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Subscriptions—In the United States, its possessions, and Mexico, $5.00 yearly; Canada, $5.50; elsewhere, $6.50 the year.

Advertising rates on application. All advertising copy subject to acceptance by publication committee.

Published monthly at Chicago, Illinois, by American Congress of Physical Therapy.

Entered as Second Class Matter June 2, 1930, at the Post Office at Chicago, Illinois, under the Act of March 3, 1879.

DISRAELI KOBAK, M.D., Editor

Suite 716 — 30 North Michigan Avenue, Chicago, Illinois

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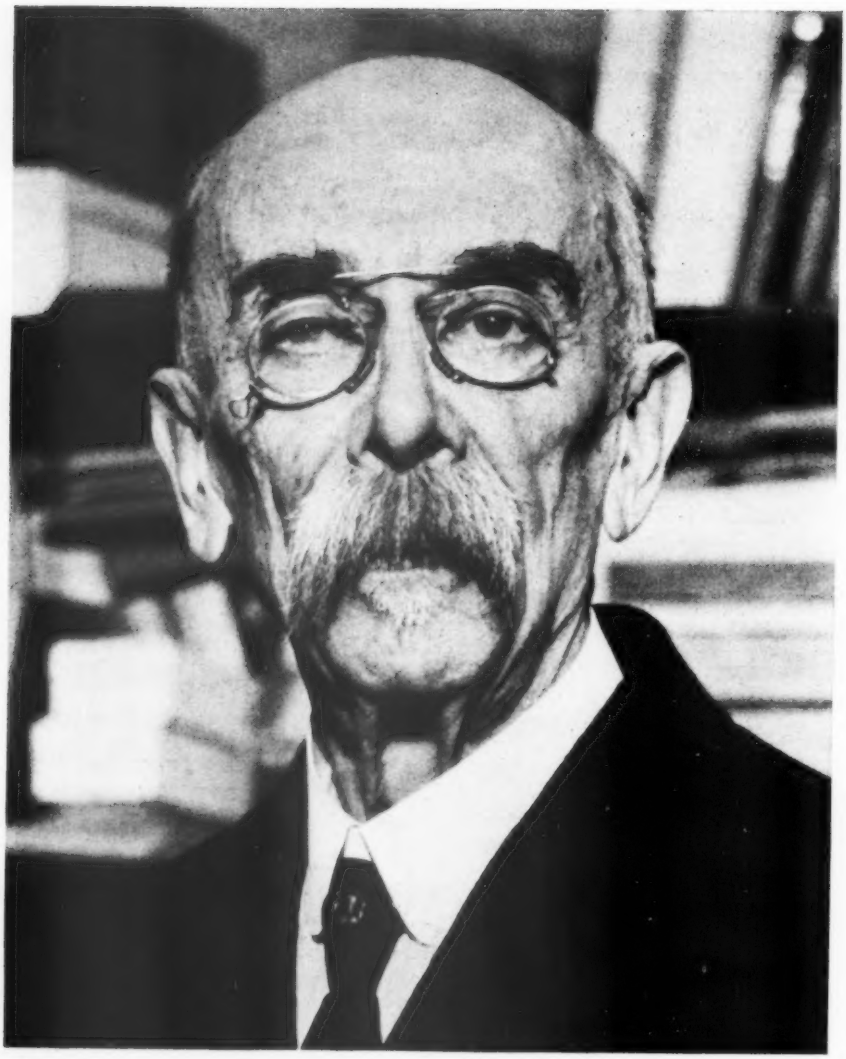

ARSÈNE D'ARSONVAL

HAIL, D'ARSONVAL!

Professor Arsène d'Arsonval, illustrious son of France, is a jubilarian on the occasion of his elevation to the rank of Professor Emeritus at the Collège de France. It was in that institution, hallowed by the memory of great intellects, that our jubilarian has for many years upheld the traditions and scientific achievements of his distinguished predecessors.

This occasion has been embraced not only in France but in other European countries to pay tribute to the great savant, both as a scientist and as a man. It is therefore meet that the American Congress of Physical Therapy add its homage to him whose long and fruitful labors in the field of science have benefited the human race.

In dedicating this issue of its official organ, THE ARCHIVES, to Professor d'Arsonval, the Congress honors itself as much as it does the jubilarian. As is evidenced by the contributions in this issue, most of which have been prepared for this special occasion, French medicine has for centuries past rendered incalculable services to the advancement of all sciences and professions.

The history of Medicine is closely interwoven with the earnest efforts of such profound thinkers of our great sister republic, as Bichat, Lisfranc, Larrey, Pasteur, Paré, Laennec, Claude Bernard, Brown-Sêquard, Charcot, Doyen, Dupuytren, the Curies, and others.

Professor d'Arsonval's labors are another milestone in the cultural history of France. We therefore send this issue out into the scientific world with the expression of best wishes on the part of the American Congress of Physical Therapy to Professor d'Arsonval for many years of usefulness to his country, to science, and to the entire civilized world.

DISRAELI KOBAK.

LABORATOIRE DE PHYSIQUE BIOLOGIQUE - HAUTES ETUDES

NOGENT-SUR-MARNE (Seine)
49bis AVENUE DE LA BELLE GABRIELLE
269

1 Septembre 1932

Cher Mr Kobak,

J'ai conservé un excellent souvenir de la visite que vous me fîtes, avec Titus, il y a quelques années à mon laboratoire de Nogent où je continue mes recherches.

Mon confrère le Docteur Morel-Kahn me fait part de l'intention amicale que vous avez de célébrer mon jubilé à Chicago.

Je suis très touché de la marque d'estime dont vous voulez honorer ma carrière à son déclin et je vous en témoigne ma vive et profonde gratitude.

En me maintenant en activité à Nogent nos gouvernants et mes chers collègues du Collège de France m'exprimaient l'espoir d'y fêter ultérieurement mes cent ans. En les écoutant je pensais à

Léon XIII qui, à pareil vœu, répondit par cette boutade: « Pourquoi imposez vous une limite à la bonté divine ?))

N'ayant jamais été pontife je ne suis pas si exigeant et j'aurais été pleinement satisfait si je pouvais visiter votre beau pays avant le grand voyage dont nul ne revient.

Mais j'aurais tort de me plaindre puisque mes amis d'Amérique me procurent la joie d'assister de mon vivant à la réalisation grandiose du but de toute ma vie: la Physico-thérapie.

Merci donc à vous et à tous les amis connus ou inconnus qui vont vous entourer.

Dites leur bien que je serai avec eux de tout mon vieux cœur reconnaissant pour célébrer le triomphe des idées qui nous sont chères.

Votre tout dévoué

D'Arsonval

de l'Institut

Professeur honoraire au Collège de France.

(TRANSLATION)

1. September, 1932.

Dear Dr. Kobak:

I have retained an excellent memory of the visit you have paid me with Titus in my laboratory at Nogent a few years ago, where I still continue my researches.

My confrère Morel-Kahn has informed me of your amicable intention to celebrate my jubilee in Chicago.

I am deeply touched by the mark of esteem with which you desire to honor my career at its decline, and I express to you my keen and profound gratitude.

Our governors and my dear colleagues of the Collège de France have expressed the hope that I would attain in the continuation of my activity at Nogent one hundred years.

Listening to them I thought of Leo XIII, who on the occasion of a similar vow, said: "Why do you impose a limit to divine goodness?"

Never having been a pontiff I am not so exacting, and I would be fully satisfied if I could visit your beautiful country before the great voyage from which no one returns.

But I would be wrong in complaining, since my friends of America afford me the joy of contributing to my existence through the great realization of the aim of my whole life — Physical Therapy.

Thanks, therefore, to you and to the known and unknown friends who will surround you. Tell them that I will be with them and appreciate with my whole old heart the celebration of the triumph of the ideas which are dear to us.

Your entirely devoted,

(Signed) d'Arsonval,
of the Institute.
Honorary Professor at the Collège de France.

THERAPEUTIC APPLICATIONS OF HIGH FREQUENCY CURRENTS *

PROFESSOR D'ARSONVAL
of the Institute
NOGENT-SUR-MARNE, FRANCE

It has become a habit to designate the diverse electric modalities applied in therapy by the name of their authors. Thus the application of static electricity is named Franklinization (Franklin), of the current of a battery, Voltaization (Volta), of the induced current, Faradization, (Faraday).

Analogously, the name d'Arsonvalization was given in 1899 by the Austrian Professor Moritz Benedikt, of Vienna, to the medical application of high frequency currents which I have introduced in therapy in 1893.

This designation was definitely adopted by the International Congress of Physiotherapy, which convened in Berlin in 1913.

What is meant by high frequency current? It is an alternating current, analogous to that of our sectors, but which reverses itself several million times per second instead of 80-100.

In therapy a good current which suffices for all applications is one of 4 to 6 million reversals per second. It produces in strong intensity no other effect than warmth. Since 1893 I have not ceased to perfect the apparatus, undertaken under my direction in the workshops of Gaiffe-Gallot. Its employment is devoid of any danger.

Successive improvements were reported at the International Society of Electricians, sessions of April, 1892, April, 1897, April, 1910, and in the Reports of the Academy of Sciences since 1881.

I began, in 1881, the study of the physiologic properties of *alternating currents of all frequencies.* I went up to only 10,000 frequencies and I was able to demonstrate their complete *innocuousness at a sufficient frequency.* From 1889 to 1892, thanks to the improvement of the technic, I could demonstrate the sound basis of my conclusion in my courses given at the Collège de France, at the Society of Electricians, to the students of Professor Bouchard, and finally, officially, to a commission named by the Academy of Sciences.

The following are the conclusions of Professor Cornu, recorder of the commission, given July 3, 1893:

"M. d'Arsonval has produced evidence before M. Marey and myself of the principal results recorded in the preceding note. We were particularly struck by an experiment in which 6 lamps (150 volts x 0.8 ampère) were made luminous by a circuit formed by our arms, the circuit being derived from the ends of a solenoid induced by oscillating discharges.

We have not experienced the least sensation by the passage of the electric flow to which we were submitted, while one could not doubt the enormous amount of energy which passed our bodies (900 volts x 0.8 ampère) equaling 720 watts or about 1 horsepower. It manifested itself either by the luminousness of the lamps or by lively and numerous sparks which were produced when the circuit was broken. The same amount of electric energy passed in the form of ordinary electric currents would have sufficed to destroy us like lightning, but under the above given conditions it produced no appreciable sensation."

I have demonstrated that in death by industrial alternating currents of low frequency one could often resuscitate the *victims* by treating them like drowned persons, that is to say, by applying *artificial respiration.* It was this report made by me in 1887 to the Academy of Sciences which has served as a basis for the regulations now in vogue. The number of electrocuted who owe their return to life to it is beyond count.

For the therapeutic employment of the high frequency currents I have indicated three procedures:

1. *Direct application,* which was later baptized *diathermy.* In this procedure the patient is placed in direct contact with the two poles of the electric source of high frequency.

2. *Condensation.* In this case the patient is laid on a bed or couch. He holds in a hand

* Special article reproduced in translation from "La Médecine" No. 9, June, 1920, as a document of historical importance. — Ed.

one of the poles of the source of high frequency. The second pole is attached to a metallic plate on which the patient lies, but separated from it by an insulator. Under these conditions the patient and the metallic plate constitute the two armatures of a condensator. The patient is crossed by a current of charge and discharge, the intensity of which grows with the capacity of the condenser. The patient, therefore, is connected with only one pole of the source.

3. *Autocondensation.* In this case the patient *has no connection* with the electric source. He is insulated throughout. The current circulates *around* him without touching him, and I simply make use of its power of formidable induction to create *in all cells* electric currents *by induction.* These currents are closed in themselves, in the cells in which they are created — hence the term autoconduction.

This power of induction is such that if the patient rounds his arms into a circle and holds in his hands an appropriate lamp, *the lamp will be lighted* by the current which originates in his arms without any communication with the source.

This then is a formidable impulse of the *total substance* which it is impossible otherwise to obtain. This is a disposition which is occasionally referred to as *the cage.*

Let us now pass to the physiologic effects of d'Arsonvalization.

1. *These currents are not felt.* They produce neither pain nor muscular contractions (controlled on themselves by Cornu and Marey, as was seen above).

An ordinary alternating current passing through the hands produces violent contractions of all the muscles of the arms and an intolerable pain at an intensity of 5 to 7 milliampères.

In my note to the Academy of Sciences, March 20, 1893, I have said: "I have been able to pass through my arms a current of 3 ampères (3,000 milliampères) without experiencing any other effect than a lively sensation of warmth limiting the intensity at the level of the wrists." Three thousand instead of 5 milliampères, that is to say a current 600 times stronger, was limited in intensity to liberating heat while at low frequency it would produce electrocution.

2. The passage of these currents is accompanied by liberation of heat in the tissues which can reach to a degree of coagulation. I have been able to attain a complete separation of the extremities of a rabbit, as I have shown in a note to the Academy of Sciences of December 30, 1901.

3. There is a production of analgesia at the points of application to the surface of the skin, especially when the current is passed in the form of a shower of numerous, very short sparks.

4. When one passes a current through the body by large uncovered plates one experiences a sensation of heat which soon is accompanied by production of perspiration and of considerable vascularization of the cutaneous surface. If one makes a small incision of the paw or ear of a rabbit in a manner that blood escapes drop by drop, one will see an abundant hemorrhage under the influence of the current, *which demonstrates an energetic vasodilating action* and lowering of the general blood pressure.

5. These currents act on microbian cells by attenuation and even destruction. They act the same way on toxins and poisons, as was demonstrated in April, 1893, by my assistant, Professor Charrin, and myself. This attenuation can take place even *in the living animal* and *in the diseased organism,* as we have presented to the Academy of Sciences on February 10, 1896.

The therapeutic applications naturally are derived from the above named physiologic facts.

I have *clinically* applied the direct current (diathermy) for the first time in the beginning of 1896, at the Hotel Dieu, in the service of my assistant, Charrin. The results obtained in the abatement of nutrition were most convincing (compare the note to the Academy of Sciences).

These results should have struck the practitioners. Nothing came of it, and the cause of it is simple. At that period there was no electricity in the hospitals. I was forced to transport the entire complicated and costly material. Again the employment required knowledge of physics to which the physicians of that period were strangers, to say nothing of their being hostile.

In short, it took sixteen years until the procedure came to us from Germany and Austria, under the name of diathermy.

Our confrères on the other side of the Rhine, better informed as a consequence of

my discussion at the Congress of Berlin, in 1913, earned a certain merit in naming the procedure d'Arsonvalization.

The applications multiply. In this article I do not intend to submit a review, leaving that for later. I will conclude by quoting what I said in 1896 in presenting the results obtained in the Hotel Dieu:

"If this new road opened to therapy is full of promise, I must inform the physicians that all is to be accomplished from the clinical standpoint. I have shown that high frequency is a powerful modifier of the organism. There, for the moment, is limited my rôle as a physiologist.

I have waited long for the physicians to respond to my appeal. I have given above the reasons for their inactivity.

As Bergonié has said: *High Frequency has come too soon to a physiotherapy too young.*

Today the march has begun. It will not be stopped. That is my reward.

PROFESSOR D'ARSONVAL *

DR. GEORGES BOURGUIGNON

Director of the Laboratory of Electrophysiology of the Practical School of High Studies, Electroradiologist of the Hospital Salpetrière.

PARIS, FRANCE

At the moment when Professor d'Arsonval has just left in the midst of full activity and glory the chair of medicine of the Collège de France, in which he has taught with the well known brilliancy during 49 years (1882-1931) as a substitute, as an associate and (since 1894) as a full professor, it is of special value to me to render homage to this great savant, who honors me with his esteem and paternal affection, by presenting his life and his great work.

His Life and Career

Professor d'Arsonval, Doctor of Medicine, comes from an old medical family of Limousin, his great grandfather, his grandfather and his father having practiced medicine there.

Born June 8, 1851 at Chateau de La Borie, in the community of St. Germain les Belles-Filles (Haute Vienne), Arsène d'Arsonval descended from an old, noble family, originally d'Arsonval (canton of Bar-sur-Aube).

One finds in the 16th century one Guillaume (William) d'Arsonval, lord of Tournelles, who appears to be the founder of this house, whose coat of arms consisted of a stripe of azure of gold and a star of eight rays intertwined and superimposed by a croslet of jaws.

In the 17th century a descendant of Guillaume d'Arsonval, named Francois d'Arsonval, lord of Tournelles and Chavignon, had several children of whom one, Simon d'Arsonval, was appointed, in July, 1690, procurator of the King in the city of Limoges. This is the Simon d'Arsonval of whom Guillaume d'Arsonval was the 5th forebear, who, leaving Champagne, became the sire of the family d'Arsonval of Limousin of which Professor d'Arsonval is a descendant.

It is plainly to this old stock of French nobility that Professor d'Arsonval owes the distinction and the fineness and at the same time the simplicity which characterize him. He belongs to the category of those of whom one says that they are "bred".

Arsène d'Arsonval began his classical studies in the lyceum of Limoges, later went to Paris to complete them at the celebrated collège St. Barbe, in order to prepare himself for the competitive test for admission to the Polytechnic School.

He was about to enter this school when the war of 1870-71 broke out. His studies being interrupted by it, he returned to Limoges, where, while awaiting the end of the war, his father, induced him to begin the study of medicine. In 1871, he was accepted for interneship of the hospitals of Limoges.

* Translated from the French by an Associate Editor.

When the war was over he found himself busily engaged in these new studies. He gave up the idea of entering the Polytechnic School and in 1873, after two years of his internat at Limoges, returned to Paris to continue in medicine, and there was at once received as an externe of hospitals (1873).

But he retained from his first mathematical studies and from his preparation for the Polytechnic School a taste for the exact sciences, especially for physics. That is also why he was attracted to experimental medicine taught at the Collège de France by the illustrious master Claude Bernard. The young externe of hospitals there pursued these courses.

I have from Professor d'Arsonval himself the story of how he entered Claude Bernard's laboratory. One day while he attended a lecture of the illustrious physiologist, a galvanometer did not function well. At the close of the lecture the young externe of hospitals went to the master and offered to fix the mounting of the instrument. Impressed by the preciseness of the explanations given by the young student, Claude Bernard invited him to prepare experiments in which electricity or physics play a rôle. Shortly after, in 1874, Claude Bernard appointed d'Arsonval as *preparator* to the Chair of Medicine of the Collège de France.

From then on d'Arsonval found his way. Abandoning his preparation for the internat of the hospitals of Paris, he entirely devoted himself to the study of physiology and especially of biological physics, and did not leave the Collège de France. Since 1876, Claude Bernard prophesied d'Arsonval's future in a letter he wrote to d'Arsonval's father, who himself had been a *preparator* for Laennec to the very same chair of medicine of the Collège de France. This accounts for the filial affection of Professor d'Arsonval for Claude Bernard. Thanks to Professor d'Arsonval one will find at the end of this article a reproduction of the autographed letter of the illustrious physiologist, which decided the career of Arsène d'Arsonval that redounded to the glory of both master and successor.

At the same time Arsène d'Arsonval, in addition to his researches, continued his medical studies and on August 6, 1877, successfully presented his thesis for the Doctorate of Medicine, entitled: "Theoretic and Experimental Research of the Rôle of Pulmonary Elasticity." This work was awarded a prize by the faculty. He was then 26 years of age.

Claude Bernard, who felt the need of a laboratory of biologic physics at the side of a laboratory of vivisection, encouraged d'Arsonval in that direction and asked for him the foundation of a bio-physical laboratory, but without success. At his death in 1878, he was succeeded by Brown-Séquard, who retained d'Arsonval to continue in the same work.

In 1882, Paul Bert, who had been a pupil of Claude Bernard and knew his desires, became minister of public instruction. He brought about a realization of Claude Bernard's demand and created for d'Arsonval the Laboratory of Bio-Physics of the Practical School of High Studies. This laboratory installed at 12 Claude Bernard St., was attached to the chair of medicine of the Collège de France.

Towards 1900 a national subscription made possible the erection of a great laboratory at Nogent-on-the-Marne. The old biophysical laboratory was moved to it and from then on Professor d'Arsonval had his residence there. After leaving the Collège de France, Professor d'Arsonval retained the direction of the laboratory and he continues to live there. At the same time (in 1882) that he was appointed Director of the Bio-Physical Laboratory, attached to the chair of Medicine of the Collège de France, Dr. d'Arsonval was called by Professor Brown-Séquard to substitute for him during the winter semester. He fulfilled this function as a substitute during five years (1882-87). In 1887, he was appointed Associate Professor at the Collège de France and he held that post for seven years (1887-1894). In 1888, d'Arsonval was elected a member of the Academy of Medicine (Section of Physics and Medical Chemistry) to fill the vacancy left by Giraud Teulon. On June 4, 1894, he was nominated a member of the Academy of Sciences (Section of Medicine), to fill the vacancy left by the death of Brown-Séquard. The same year d'Arsonval was appointed to the full professorship of medicine of the Collège de France, where he continued on the path beaten by the great physician-physiologists, Laennec, Magendie, Claude Bernard and Brown-Séquard. D'Arsonval's researches became famous throughout the world when the investigator was only thirty years of age. It was, however, at the age of forty-three when

Fig. 1. Prof. d'Arsonval's Laboratory, Nogent-Sur-Marne

d'Arsonval began to climb the rungs of the ladder of science until he reached the very top of his career.

During his long career d'Arsonval has seen the bestowal on him of all honors without having sought them. As a member of the Academy of Sciences he became the President of that body. As a member of the Society of Biology he became its Vice-President and at this moment is its President. Among others he took active part in most of the scientific societies: the French Society of Electrotherapy and Radiology, of which he was made Honorary President after having been its President, sharing this honor with the illustrious physician-physicist, Branly; the Society of Physics, of which he was President; the International Society of Electricians, of which he was Vice-President; the Society of Civil Engineers, of which he is an honorary member. Since the great International Congress of Electricity, of 1881, d'Arsonval was its secretary and an active member of the commission for the unification and fixation of electric units, which today are accepted throughout the entire world. At the World's Fair of 1881 and of 1889, he was a member of the jury of awards.

A number of industrial societies have appealed to him for advice and have secured him either as a counsellor or as a member of their administrative councils. D'Arsonval was one of the founders of the International Institute of Refrigeration.

Created a Knight of the Legion of Honor in 1884, he has rapidly been accorded all grades of this order and was promoted to the supreme distinction of the Grand Cross of the Legion of Honor in 1931, in connection with the fete of the fourth centenary of the Collège de France.

Professor d'Arsonval's career has run a perfectly regular course, in the greatest sereneness and without shocks. It is one that can be said to be an image of the man himself.

Always affable, of an ever even temperament, without any mental reservation, Professor d'Arsonval at Nogent-on-the-Marne leads the simplest, the brightest and the most beautiful life one may behold. It is truly a great comfort to be received by him without ceremony on a Sunday in his simple workroom, equipped with a library and tables covered with manifold publications, or in the small reception room of his own apartment. The visitor feels at once at ease in his presence, and secures without ado his advice, his science, and, if need be, his support. He generously offers suggestions, and many labors have been born in the fruitful conversations with one or the other visitor. It is thus that a goodly number among us can call themselves his disciples, without having been it in the common sense of that word. Among those who have truly been his students, his favorite is Georges Claude, who has for his master a touching devotion which he

has not hesitated to proclaim to the world.

Personally I cannot forget the welcome I met when without knowing him I went after the death of my lamented master Dastre — who was his friend — to ask him to present for me a note to the Academy of Sciences. Since then I have myself received repeated proofs of how much he encourages efforts, helps against discouragements, which every research worker experiences at times, and gives advice of great sagacity and deep common sense. Naturally sentiments of affection are never lacking between d'Arsonval and those who apply to him. While d'Arsonval is a great savant, he is also a profound philosopher with a clarity of mind seldom encountered. He is, therefore, far from being a devotee of one limited specialty. His general culture has enabled him to create works in varying directions. His heart equals his mind and his simplicity equals his kindness. One is not surprised after one has had the great chance of being welcomed by him and after repeated visits, at the astonishing ease with which his career has developed, a career whose acclaim is justified by the importance of his works and of his discoveries.

His Labors

As I have said above, it is the direction of biophysics which the researches of d'Arsonval have taken from the beginning in the school of Claude Bernard.

To regard d'Arsonval merely in the light of his general popularity as an electrophysiologist and as the originator of high frequency therapy is tantamount to ignoring the great extent and variety of his researches. The manifold labors of variable nature he has accomplished contemporaneously render their chronological classifications well-nigh impossible.

Variety of direction was evident from the very moment he entered the laboratory of Claude Bernard. Between the years 1873 and 1877, he has published almost simultaneously the results of his researches on the elasticity of the lungs, on animal heat, and on thermoelectric needles, which he employed for the researches of Claude Bernard. The latter has expounded them in his lectures on operative physiology of 1877, published a year later after his death through the efforts of Mathias Duval.

One can therefore say that it was from the first four years of his scientific life that d'Arsonval approached the principal type of research he subsequently pursued, which led to the fundamental discoveries that made him a celebrity.

In whatever directions he labored, d'Arsonval has himself forged the instruments for his researches. He invented a considerable number of apparatus. Some were specially intended for the biologic sciences, others were of a general order, and while intended to serve physiology, found their way into the domain of industry. From this we see the dual quality of d'Arsonval — on one side as a physiologist and physician, and on the other as a pure physicist. We observe that alongside of his scientific life he also plays a great rôle in a number of industrial organizations, which owe him powerful means of productivity.

For his researches in calorimetry he invented a number of important appliances, diverse calorimeters, thermostats, now used daily in the laboratories of physiology, biology and bacteriology; a thermogalvanometer, etc. For his researches in respiration he has devised procedures for the measurement of gases, of blood, of liquids of the organism, of urea, etc.

For his researches in electrophysiology he has created nonpolarizable electrodes of silver and of chloride of silver, from which were developed Lapicque's electrodes for animal physiology and those of my own for human electrophysiology and electrodiagnosis.

In this domain he modified Deprez' galvanometer and created the mobile galvanometer, voltmeters, coulombmeters, thermoelectric appliances, a telephone, microphones, the myophone, etc., and all apparatus of high frequency. These inventions have proved of service not only to physiology, but also to industry (galvanometers, telephone, etc.). D'Arsonval's apparatus for the production of high frequency currents, constructed for physiologic and medical study, have become without alteration the appliances for wireless telegraphy. Though Hertz has given us the electric oscillations and Branly the receptor, it was d'Arsonval who provided the procedures for the production of waves utilized in radio-telegraphy and in radiotelephony. These three names must therefore be associated in the discovery of wireless telegraphy. When the sending station of the

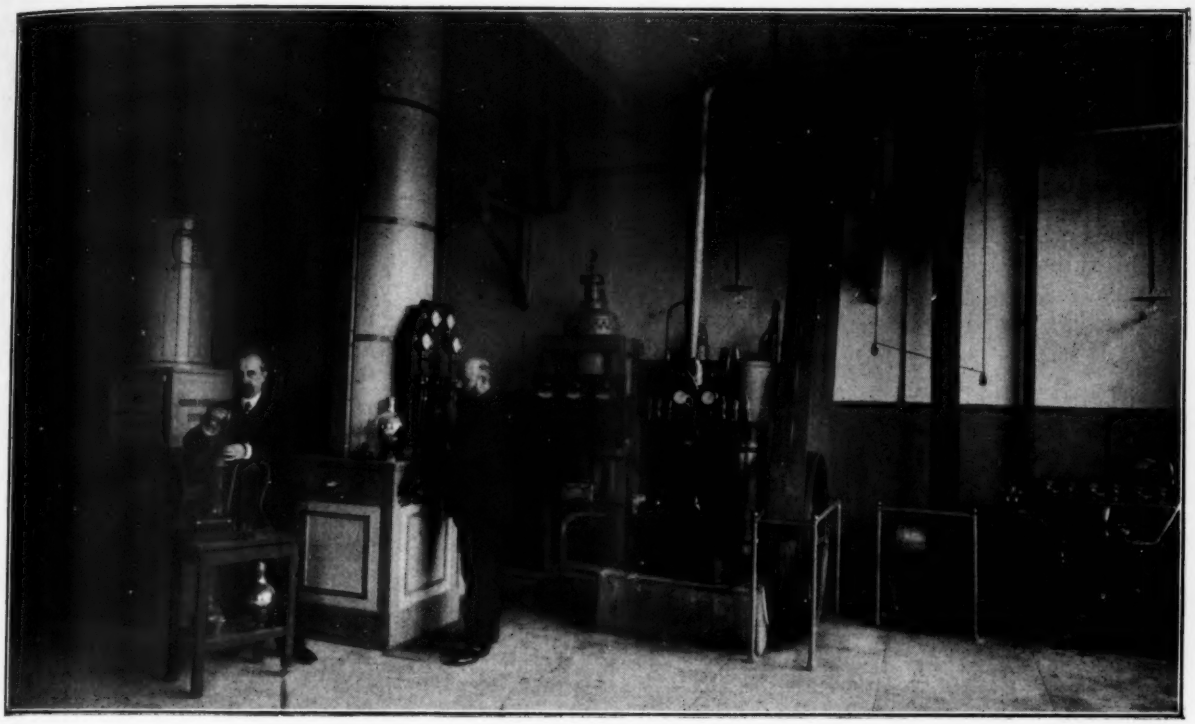

Fig. 2. Laboratory of Prof. d'Arsonval.

Eiffel tower was established it sufficed to carry to it the emitting material of High Frequency of d'Arsonval.

For the study of the action of low temperatures, on living tissues, d'Arsonval had recourse to liquid air as a refrigerant, which he himself manufactured in his laboratory. To preserve it he invented the double-wall bottle which since has been named "Thermos bottle." The report on this subject to the Society of Biology was made in 1888, five years before the publication of J. Dewar, who merely silvered by mercury the exterior surface of the inner receptacle. It is therefore erroneous to ascribe the paternity of the "Thermos bottle" to J. Dewar, as is occasionally done. This appliance originally created for physiology, has also become the starting point of the industry of artificial cold — with d'Arsonval being one of the founders of the "International Institute of Frigeration."

One can appreciate from his rapid résumé of his inventions why some of d'Arsonval's students were biologists while others were not, as for example, Georges Claude.

While this technical work alone would suffice to render a man illustrious, it has, however, been only a preparatory part of d'Arsonval's work. As a matter of fact he had no aim of becoming an inventor, except to solve biologic and physiologic problems, and he actually was an inventor only because he was forced to create needed apparatus which did not exist or, if they did exist, to perfect them.

The biologic results of d'Arsonval's researches may be grouped under four heads, the fourth of which I will treat more extensively, as it is of particular interest to electrophysiologists and electrotherapists.

(1) *Research in Respiration and Pulmonary Toxins.*

D'Arsonval investigated this type of respiratory problems by a preliminary study of pulmonary elasticity, a work which, as was said, was the subject of his doctorate thesis in 1877. In that work d'Arsonval shows that pulmonary elasticity has two causes, the elastic fibers and the tonicity of the muscular fibers. Later he established *experimentally* the rôle of the lung as an antagonist of the diaphragm, dilating the auricles, which act by suction during the diastole, and the rôle of pulmonary elasticity in the creation of a pleural vacuity, which maintains the dilata-

tion of the pulmonary vessels, with the maximum at the end of respiration. Finally he demonstrated the influence of the pneumogastric nerve on the retractility of the lung. As a result of this, d'Arsonval, in collaboration with Brown-Séquard, studied the pulmonary toxins and demonstrated the importance of non-vitiated air for consumptives, because pulmonary poison is an organic alkaloid and not carbonic acid. He gave procedures for the purification of expired air.

His researches on pulmonary toxins were the first steps in the study of internal secretions, which we will now discuss.

(2) *Research in Internal Secretions.*

Always in collaboration with Brown-Séquard, d'Arsonval has provided a basis for the therapy by internal secretions, the first idea of which was advanced by Claude Bernard.

In 1891, d'Arsonval said at the Society of Biology: "*The question, therefore, looms large, and we now believe, that all tissues, glandular or not, give something special to the blood; that every act of nutrition is accompanied by an internal secretion. We believe as a consequence that the tissues could and should be used in special cases as a method of treatment; that there is need for a new therapy, the medicines of which will be the products manufactured by the different tissues of the organism; that all cells of an organism are thus rendered independent of each other by a mechanism other than the nervous system.*" The development which this idea has undergone in modern therapy under the names of endocrinology and endocrinotherapy is well known. While a part of the preceding labors have been made in collaboration with Brown-Séquard, whose associate d'Arsonval was, the following labors we are about to expound, represent the principal part of d'Arsonval's work, accomplished by him independently.

(3) *Calorimetry and Animal Heat.*

D'Arsonval has occupied himself with this question concurrently with the preceding labors during the first years of his researches. Since 1876, he has cleared up the problem of constant temperature. D'Arsonval has shown by his calorimetric studies that a careful distinction must be made between thermometry and calorimetry. Though thermometry informs us about the distribution of animal heat, it provides no information whatever about its production. As a matter of fact either the central or peripheral temperature of man or animal shows at a given moment a complex result of production and of loss of heat. Calorimetry, on the other hand, informs us about the production of heat. Through it we learn that a rise of temperature may correspond to a diminution of the production of heat, if there is a slowing of loss of heat, or, contrarily, a lowered temperature may correspond to an excess of heat, if there be greater waste and loss of heat. D'Arsonval was led to study the production of heat by animals, loss of heat by radiation, and he has shown by exact experiments on different animals that birds have a higher temperature than mammals, although they produce less or at best as much heat as the latter. This d'Arsonval ascribed to the feathers, which hinder loss of heat better than fur. He also established that the emitting power of the skin is enhanced when it is greased, as for example by coating with linseed oil.

He followed this up with studies on himself and different animals concerning the influence of numerous factors on calorimetry, such as weight, stature, species, tegument, abstinence, light, fever, external temperature, different coating or varnishes applied to the skin, etc. These researches could not have been accomplished but for the invention of his registering calorimeter.

It was during the course of these researches that he was led to study low temperatures and their action on microbes. He gave a procedure of rapid sterilization of organic liquids by liquefied carbonic acid, and he discovered the bactericidal action of carbonic acid at high pressure. These biologic researches, moreover, led him to a purely physico-chemical study of carbonic acid at high pressure, resulting in the discovery of new chemical functions of carbonic acid under these conditions (1891).

(4) *Electricity and Light.*

If I discuss d'Arsonval's researches on electricity and light in one section, it is because these two types of studies are connected and have sprung from each other.

The beginning of these researches is contemporaneous with others and goes back to d'Arsonval's appointment as preparator by Claude Bernard at the Collège de France.

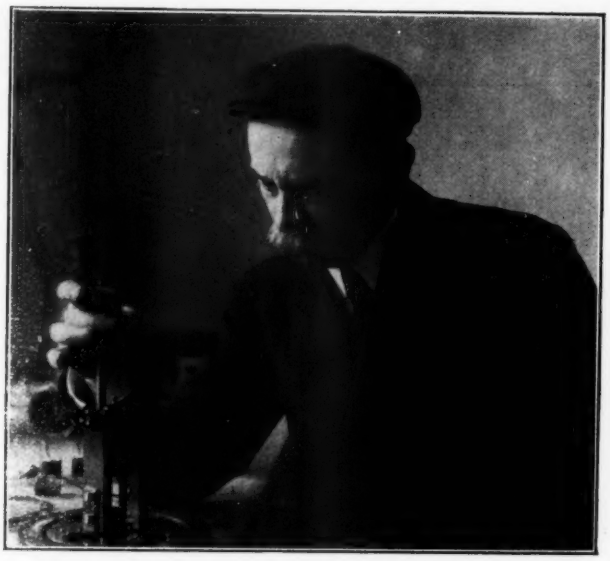

Fig. 3. Prof. d'Arsonval preparing liquid air.

Entering the path of electricity through the study of thermo-electric needles and of all his appliances for the measurement of temperature by electrical means, d'Arsonval lost no time in interesting himself in physiologic electricity from two viewpoints, namely, of the living being as a *generator* of electricity, and of the living being as a *receptor* of electricity. In other words he has successively studied the *production* of electricity by living beings and the *effect* of electricity on them

It is for these studies that he first of all constructed nonpolarizable electrodes of silver and of chloride of silver and a galvanometer with a movable mounting, universally known under the name of Deprez-d'Arsonval galvanometer. He was the first to perfect a galvanometer at once very sensitive and rapid. It was in pursuing the same idea that d'Arsonval has thought out the use of the telephone as a galvanoscope (1878). This procedure is still being used. It was while thus working with Paul Bert that he was led to create new microphones (1879).

Equipped with such instruments d'Arsonval first studied the so-called dormant currents, and he demonstrated that these currents are "correlatives of the chemical function of protoplasm."

Later he took up the currents of "action" or negative variation, which he explains by the variation of the superficial tension of the protoplasm, produced by its change of form. He thus harmonized the theory of negative variation with the general theory of Lippmann, who has demonstrated that every variation of the surface of separation of two non-mixing liquids produces an electric tension, and that reciprocally, every electric action alters that surface.

He further succeeded in demonstrating that the heat liberated by muscular contraction is not caused by it, but is the result of transformation into heat of the electric current produced by chemical reactions. Part of that current circulating in circuits closed by the tissues themselves cannot be secured in electrodes, which gather only an infinitesimal part. The muscle, therefore, is "much more an electric transformer of chemical energy than a transformer of heat."

From his studies of negative oscillation d'Arsonval has drawn the explanation of the origin of electricity in electric fishes, whose electric organ is only a modified muscle. Finally he has studied the production of elec tricity in man. D'Arsonval himself presents the following general conclusion of all his labors:

"One sees by the preceding considerations, that the fascinating law discovered by Lippmann permits the attribution to one and the same cause of phenomena which as negative oscillation appear to have no connection between electric discharge of fishes and contraction of protoplasm.

Thus d'Arsonval was the first who has given through his experiments a generally ac-

cepted scientific explanation of all phenomena of animal electricity.

Having elucidated this first series of questions, d'Arsonval attacked the inverse question — that of the action of electricity on living beings.

Naturally he first studied the most striking phenomenon which has long aroused the sagacity of physiologists — the *electric excitation of nerves and muscles.*

Though d'Arsonval has not found the law of excitation, the discovery of which was made by Noorweg, the precursor of Weiss. whose labors were the starting point for Lapicque in the discovery of chronaxia which I succeeded in applying in human physiology and in electrodiagnostics, he nevertheless, was the first to have shown that the quantity of electricity plays a rôle at least in the direct excitation of muscles, and it was he who has introduced the condensers in the technics of electrophysiology (1889). For it is by the use of condensers that Noorweg discovered his law. Here, then, d'Arsonval was a precursor who must not be forgotten. It was he who gave the idea of the *electric wave* and who showed that it is a *characteristic of excitation* by its registration as a *curve.*

It is his researches that have led to the employment of sinusoidal currents which he has introduced in electrotherapy, thanks to the clinical investigations by Dr. Apostoli. D'Arsonval also created an appliance for the production of sinusoidal currents.

Finally, in studying the influence of frequency on excitation, he was led to go from low to high frequency and to create every apparatus needed to produce the electric osillations discovered by Hertz.

Starting out from his experiments with the sinusoidal currents, which, when they are greatly spread out, no longer excite either the muscles or the motor and sensory nerves, while producing profound modifications of nutrition, through the increase of absorbed oxygen and of liberated carbonic acid, d'Arsonval has shown that it suffices to change the form of the wave to regain excitation. At low frequency one obtains isolated shocks; on increasing the frequency, (20 to 30 excitations per second for human muscles), the muscle becomes tetanic. The excitation increases with the frequency, but not indefinitely so. Beginning with 2,500 to 5,000 excitations per second, excitation diminishes with the increase of frequency. In December, 1890, by substituting for his apparatus which could produce no more than 10,000 excitations per second, Hertz's apparatus, which gave several *billions* of excitations per second, d'Arsonval saw the disappearance of every muscular or nervous excitation, motor or sensible. On the other hand one could pass the current through the organism without harm and with intensities which would kill by lightning if the frequency were lowered — *thus were discovered the fundamental facts which serve as a basis for the entire therapy by high frequency!*

D'Arsonval devoted himself to the study of these interesting currents, created generators of high frequency which carry his name, demonstrated the physiologic effects of the high frequency currents, direct or induced and disclosed the production of heat by these currents. In other words, without having created that term, he has furnished everything needed to make *diathermy* the success now known by the entire world.

A few experiments, simple and striking, made repeatedly, enabled him to establish these facts. After having originated the therapy by internal secretions, d'Arsonval developed the then existing physical therapy and created two important branches of this therapy — the sinusoidal currents and the high frequency currents.

Accordingly, physiologists, physicians and particularly physiotherapists, owe much to d'Arsonval, as indeed all electrophysiologists consider him their master. It is easy to understand that, studying the physiologic effects of electricity and their therapeutic applications, d'Arsonval naturally was led to study also the ill effects, i.e., the accidents and deaths by electricity. This side of d'Arsonval's researches was the starting point of the beautiful labors of Professor Jellinek, of Vienna, Austria, who devoted his life to the study of the accidents of electricity under the name of "Electropathology." D'Arsonval has shown that while the constant currents of high intensity can produce destructive and incurable lesions, it is not the same with alternating currents. These, even at great intensity, produce above all phenomena of *inhibition* with death being only an *apparent* one. By treating the victims the same as drowned persons, and by employing artificial respiration, they are often brought back to life, as d'Arsonval himself

Fig. 4. Prof. d'Arsonval testing his high frequency solenoid.

actually has demonstrated it. On these facts, d'Arsonval has protested against judicial electrocution practiced in the United States as a barbarous and unreliable procedure. Accordingly, d'Arsonval has rendered the greatest service to medicine and humanity, which owes to him the saving of numerous lives.

Pursuing farther the study of electrocution, d'Arsonval has shown that the production of heat does not follow Joule's law and consequently is not due exclusively to the passage of the current. It is due to excessive contractions of all the muscles. Taking up recently the question of high frequency again, he has shown that the production of heat in more and more concentrated salt solutions no longer follows Joule's law. The data of the thermomilliamperemeter are therefore insufficient in electrotherapy.

In addition it is a long time since d'Arsonval believed that the production of heat is not everything in the therapeutic action of high frequency. By experiments in collaboration with Charrin, he has shown that the action of high frequency currents on the toxin of the bacillus pyocyaneus takes place even when one prevents the heating of the culture by maintaining it at a low temperature by his procedures of refrigeration. The entire therapy by high frequency currents should be called: "Darsonvalization," as all applications that have been made with them, are directly derived from d'Arsonval's researches.

Though the "diathermic" aspect appears momentarily to predominate, it would be unjust to abandon the other modalities of high frequency, not only the sparkings and high tension emanations but also the condensation bed and cage, of which I remain a loyal adherent.

D'Arsonval has thus covered the entire gamut of physiologic electricity, animal electrogenesis, physiologic action of electricity, accidents, and death by electricity, and therapeutic actions of electricity.

The phenomenon of excitation, a general and common phenomenon of living substance, not being exclusively due to electricity, led d'Arsonval to compare mechanical excitations and excitations by another form of oscillation — light — with e l e c t r i c excitation. D'Arsonval attained the tracing of the curve of *mechanical pressure* on the nerve subject to excitation, as he had traced that of *electric pressure*. He has obtained a characteristic of mechanic excitations that is identical with that of electrical excitation. Following this up with light, he has shown that when a muscle is subject to intermittent illumination, the series of illuminations act like a series of electric excitations and the muscle contracts, but this contraction is very feeble and not perceptible except by the sound given off by the myophone. The phenomenon of excitation is, therefore, very general and its law is the same for all forms.

This study of the excitation of muscle by light has led him to investigate the action of

light on microbes, later the photography of the spectrum of absorption of hemoglobin, which reveals a strip invisible to the eye, providing medico-legal applications. Finally he has invented a differential spectrophotometer without polarization and has studied incandescent light by the gas burner of Auer and has shown the excellence of that light for microscopic investigation and spectral analysis of photography.

* * *

I think the above suffices to show the extent and variety of d'Arsonval's works and at the same time the connection which binds one to the other. In turn, physicist, physiologist, physician, d'Arsonval has completed every question he has touched, guided by the mastering idea — the application of physics to the study of the phenomena of life. Of a marvelous ingenuity, aided by great manual skill and leaning on an immense general culture, d'Arsonval has been able to search out the most diverse problems with a rare depth. Unable, unlike certain great savants, to remain content with purely speculative theory, he had no fear in following up the practical applications of his theoretic discoveries. These two aspects of his activity suffice to illustrate the man. From our point of view as physiotherapeutic physicians it is to him that therapy by physical agents owes the heights it has reached today and which it will yet attain. His success justifies the words he said in 1881: *"I am convinced that the therapy of the future will employ as remedial agents physical modifiers (heat, light, electricity and agents yet unknown).*[1] *The barbarous means which under the pretext of curing us consist of poisoning us with the most toxic drugs of chemistry, shall cede their place to physical agents, the employment of which has at least the advantage of not introducing any foreign body into the organism."*

Worthy of his noble ancestors d'Arsonval presents the example of a beautiful life with a beautiful and great work accomplished. He has the joy of witnessing the success of his ideas and of the development of what he has sown, and of possessing the affection of all who have the privilege of knowing him.

(1) The discovery of x-rays and of radium and the advent of radio- and radium therapy fall in this category.

Translation of the original letter from Claude Bernard to Dr. d'Arsonval, Sr.

40, Rue des Ecoles.

Sir:—

You express in your letter sentiments which I already knew through your son Arsène. I know that you count on him to be at your side and to comfort you towards the decline of your medical career, and that it is a great sacrifice on your part to be separated in order to enable him to engage in Paris his scientific pursuit. I understand, sir, and I fully respect the natural conflict between the heart of a father and that of a good son. All that I can say to you is, that for my part I have taken your son to my heart and I appreciate him more and more. I have seen few young men so well endowed for the cultivation of the sciences as he. He possesses great learning, a noble spirit, and a taste and enthusiasm for theoretic and practical problems, to which must be added a character at once lovable and obliging, which has endeared him to his comrades and all who know him. You will understand, sir, that it is very difficult for me under these circumstances to fail to encourage him, and I believe it to be my duty to accord him my affection and support in a career in which I believe him destined to succeed.

Doubtless scientific careers are not always so rapid in their immediate results as the professional careers properly so called, but they have other features which compensate those who persist in them. Furthermore, for the moment there can be no question of diverting your son from his medical studies, as the very contrary is the case. We have terminated the courses at the Collège de France and your son will be free until the month before December. I have induced him to profit by it to pass his examinations in medicine, so that he will attain the Doctorate towards January, 1877.

Your son is still young enough to have the time for reflection before deciding on a definite step, but so far as I am concerned, I will always encourage him for a scientific career, which, as I have already told you, I believe holds for him a beautiful future.

Kindly accept, sir and dear confrère, the expression of my most devoted sentiments.

(Signed) CLAUDE BERNARD.

Paris, 6 July 1876.

D'ARSONVALIZATION *

Its Principal Applications

L. DELHERM and MOREL KAHN
Chief of Service, Chief Associate of Service
Electroradiologie Department of the Hospital de la Pitié

PARIS, FRANCE

We believe that we can render no greater homage to the eminent Professor d'Arsonval than by reviewing the manifold applications of the high frequency currents in therapy, justifying the name of "d'Arsonvalization," which was adopted by the International Congress of Physiotherapy, in 1913, at Berlin, for the designation of this electric modality.

General Consideration

We must recall that high frequency currents are alternating currents the alternations of which are much more rapid than those of the commercial alternating currents, and that they can attain several million periods (cycles) per second. *Frequency* constitutes one of the characteristics of high frequency currents. Others are: 1. *Wave length,* (i. e., the product of the division of the speed of transmission of electricity: 300,000,000 meters per second by the frequency). This varies between 150 and 800 meters for medical apparatus, running to 50 and 8 meters for short wave appliances, and even less than one meter for apparatus of ultrashort waves, which are beginning to be utilized in therapy.

2. *Form of Waves,* which varies according to the use of spark gaps (damped waves) or radio tube appliances (sustained waves).

3. *Intensity.*

4. *Voltage.*

In varying these last two factors one obtains:

(a) With an increased intensity and low voltage, so-called actions of quantity or intensity. These are utilized:

(1) For diathermy.

(2) For diathermocoagulation or hot sparking.

(b) With a feeble intensity and increased voltage, so-called actions of tension, which serve for effluvation and for fulguration.

(c) A modality between the above two to which belongs the electric knife.

It is not our purpose here to study theoretic problems and we will merely state that the *power* of an electric current is expressed in watts, (i. e., the power produced in one second by a current of one ampere under difference of potential of one volt, that is to say, in a resistance of one ohm). In alternating current this power is weaker and equals:

$$W = R I^2 \cos \gamma$$

(Cos γ being the factor of power more equal and often less than I.) The *heating* of a conductor through which is passed an electric current is proportionate to the power and to the time of application.

From the point of view of medical applications a current of a power of 100 watts, in general application, should heat in half an hour a patient of 70 kilograms by 0.6° C., but because of radiation, transpiration and respiration which eliminate a large number of calories, one never attains such an elevation of temperature. It becomes necessary in order to attain a pronounced elevation of temperature to maintain long séances with appliances of great power (at least 500 watts). It is important in high frequency to take into account two particular points:

1. *Effect of the Induction Coil.* In the alternating current the coil tends to oppose itself to each alternation. In high frequency the lengthening of the conductors in use or the helixes they can make, diminish the available power.

2. *Effect of Capacity.* In the circuit of a continuous current a condenser absolutely stops the passage of the current. On the other hand, in an alternating current, it allows at every alternation the passage of a quantity of electricity proportionate to its capacity. This quantity will, therefore, be the greater the more the frequency increases, so that for a sufficiently great frequency a very small condenser will make possible the obtaining of a serviceable current.

Consequently: (a) When one considers

* Translated from the French by a member of the editorial staff.

the condenser formed by a metallic electrode (conductor), the skin (insulator) and the muscle (conductor), the resistance of the skin becomes practically negligible. (b) One obtains an important current when one considers the condenser constituted by the metallic electrode (conductor), the vestments of the skin (insulator) and the human body (conductor). It is this arrangement to which one has recourse when one makes use of autocondensation beds or when one performs diathermocoagulation by capacity. (c) The insulated body of the patient constitutes a condenser sufficient for the charging current to be intense enough to produce small coagulations. That is the disposition for monopolar coagulation.

Physiologic Effects. Without stressing it, we will simply say that the high frequency currents possess:

(1) *A thermic effect,* measurable, but which the patient does not feel;

(2) *Electric effects,* namely,
Analgesic,
Equilibrative,
Sterilizing,
Stimulating, of the endocrine glands,
Circulatory,
Nutritional.

We may be permitted to emphasize that from the beginning Professor d'Arsonval succeeded in demonstrating these electric effects of high frequency currents and that they have remained for a long time unknown because the intensity of the thermic effect has rapidly eclipsed them.

Applications of Currents of High Frequency in Therapy

We may divide the therapeutic applications of the high frequency currents into medical, and surgical applications.

Medical Applications are those which *do not produce* destruction of tissues. They consist of:

(1) Quantitative Applications: Diathermy, autocondensation cage, autocondensation bed.

(2) Tensile Applications: Effluvation.

A. *Diathermy.* Employed in this form the currents of high frequency develop heat in the very tissues, which Professor d'Arsonval has at first designated as the direct application of high frequency. When one applies diathermy it is proper not to injure the tissues by utilizing a weak voltage and weak density of current. All high frequency appliances enable the application of diathermy under conditions of diminishing the length of the spark and of using a stout solenoid of which one may make use of only a few spirals. Manufacturers have succeeded in producing numerous models of apparatus, called diathermic, particularly adapted to this modality.

The *temperature attained* in diathermic applications will vary in the neighborhood of 40-41° C. and should never exceed the latter figure. Numerous methods have been devised to measure the rise of temperature in an accessible part of the body (vaginal thermometer, rectal thermometer, pyrometer), but until the last few years one did not possess the means of exactly knowing the distribution of heat in the depth of tissues which with densities of strong currents is not homogeneous.

Pariseau, of Montreal, has precedence in researches on this subject which are of greatest interest. He made use of a gelatinous substance, colored yellow by a chemical compound with a property of becoming red at a temperature between 37° and 42° C. These experiments have been taken up in France by the engineer Walter and the results secured by these two authors have demonstrated some particular points:

(1) As a result of an electric phenomenon called "border effect" the electric density is greatest at the edges of plates than in the center, greater also at a sharp than at rounded edges.

(2) To obtain a regular diathermic effect it is essential to place the electrodes as soon as possible in a manner so that they be equally apart (the greatest portion of the current always passing by the closest parts). Moreover, the thermic effect will be the greater the closer the electrodes will be to each other.

(3) It must be borne in mind that the current seeks to go around the bony parts in its path and that on the other hand it is attracted by the conductor bodies which it can reach (metallic bodies, plates of composition). It is interesting, therefore, to attempt to evade these phenomena by a rational arrangement of the electrodes.

Such are the principal results obtained by Pariseau and Walter, but other considerations must equally be taken into account with regard to the application of diathermy, namely,

(1) The nature of the electrodes. One may utilize:

(a) Metallic electrodes, such as plates of fine tin, metallic mesh, thick metallic plates, jointed, etc.

It is particularly interesting, especially at the level of regions difficult of application, to apply electrodes either shaped for the region to be treated (electrodes of Morel Kahn for the hands) or pliable electrodes to be moulded at will, as those advocated by Surmont and which are made of a metallic cloth on a waxen background, which can be moulded after softening in warm water over the part to be treated (shoulder, elbow, hip, etc.).

(b) Moist electrodes, as gauze pads, which must be soaked in a saturated saline solution (CaCl or NaCl) to avoid their being dried out under the influence of the heat; felt electrodes, covered by metallic cloth (like those we use in the Pitié hospital), with which contact with the skin is assured by the metallic cloth, the felt playing the rôle of a moist electrode. (Care should be taken to insulate perfectly the edges of the metallic cloth.) When one uses short wave apparatus the current does not pass by conductibility but by capacity. One can then use insulated electrodes, since there is no need of applying them to the skin. To obtain strong intensities, it is then necessary to make use of electrodes of large surface and of powerful apparatus. (One must then look out for metallic pieces, interposed between the patient and the dielectric, which may become sufficiently heated to melt, as has been observed with watch chains.)

2. *The Regions where the Electrodes are Fixed.* The greatest possible precautions should be taken when the skin is poorly moistened and when there is a thick layer of fat.

It must not be forgotten when one treats extremities that the regions between the electrodes become heated more intensely as their cross section is smaller in size, that the tissues are less vascular, that they are poor conductors (presence of bones), also that the joints are heated more rapidly and more intensely than the rest of the extremity. One should therefore in such cases employ only weak intensities (e. g., wrist, ankle). On the other hand, the richer the circulation, the better the tissues can sustain the current, that is why on the mucosa, one can employ greater intensities than on the skin.

(3) *The Fixation of the Electrodes.* The electrodes must always be perfectly adjusted to the skin and contact must be assured throughout the entire duration of the treatment to avoid the risk of burns. At the same time one must take care not to stop the circulation of the blood and not forget that when the electrodes are unequal in size, that the heat will be more intense under the smaller electrode.

Precautions. (1) One should never subject a patient to diathermy without being sure that he can feel thermic sensations (children, obese, sufferers from syringomyelia, etc.) or, if treatment must be given under such conditions that great prudence is not omitted in utilizing minimum dosage.

(2) One must never attempt to obtain a determined dose at any cost.

We consider it to be a great error to desire to fix by a figure in milliamperes the dose to be utilized in diathermy. It is this tendency one often finds stated by manufacturers of apparatus and even by electrotherapists in articles or even in their books. Besides the expression of doses in milliamperes as functions of the apparatus, it is essential to know that all patients do not stand the same intensity in the same region equally, and that the sensitiveness of one and the same patient may vary from day to day. To be free from danger, all applications of diathermy should always be pleasantly supported, and the patient should be convinced that it is to no good purpose to employ too high a degree of heat.

(3) Whenever this will be possible one should aim at establishing the temperature of the applications. It must not be forgotten as a matter of fact (a) that a pleasant heat at the beginning of a séance may rapidly become intolerable, hence the necessity to diminish the current if not to interrupt it for a few moments.

(b) That the analgesic effect of the current may after some time facilitate toleration of increased doses. As a general rule a pleasant heat acts equally well if not better than an increased degree. The electric effects are often as important as the thermic effect.

To measure the temperature recourse may be had (a) at the surface to a pyrometer pushed under the edge of an electrode nearest the other. In practice, one will not exceed 41° C. at the skin and 42° C. at the mucosa (temperature very close to that of coagulation, and which should arouse our greatest pru-

dence). A good precaution is to have the operator touch the skin with his finger during the treatment (near the electrodes, at the level of narrow regions of extremities) to make sure of the attained rise in temperature. (b) In the depth (rectum, vagina, urethra, etc.), by means of thermometric electrodes, by recalling that the registration of the thermometer is lower and slower than the true temperature.

(4) The patient should never be left under treatment without supervision.

Contraindications. They are few. We cite:

Febrile states.

Disturbances of thermic sensitivity (syringomyelia, very young children, etc.).

Acute neuritis, where diathermy may increase the pains.

Let us not forget that if the circulation of the patient is good, vasodilatation is sufficiently effective to overcome the heat engendered by diathermy, while in the opposite case there is great risk of causing burns.

Incidents. Accidents. These are virtually negligible if contact between electrodes and tissues is perfectly sure.

They are:

1. Tinglings. When bare metallic electrodes are used the patient often complains at a comparatively weak intensity of tingling and perhaps of slight sensations of burning. The tinglings generally disappear when sweating begins and one can avoid them by wetting the skin before beginning the treatment. As regards the sensations of burning they appear most often through slight irregularities of the edges of the electrodes (bends, clefts) producing exaggerated, localized densities which may cause small burns. They are avoided by making use of electrodes in perfect condition and perfectly applied.

2. *Faradic Sensations.* These sensations which, in certain cases, may even produce a muscular contraction, are observed since the introduction of apparatus with spark gaps and are due:

(a) To a poor contact in the circuit of high frequency.

(b) To an increased separation of the spark gap.

3. *Burns,* which may be superficial or deep.

(a) Superficial burns may be due:

(1) To defective metallic electrodes (see above).

(2) To desiccation at a point of a wet electrode, and it is to avoid such a too rapid desiccation that one will prefer the use of electrodes wetted with saturated saline solutions.

(3) To lack of sensibility or to too great a tolerance of the patient who does not call the attention of the physician to an abnormal sensation.

(b) These burns may be of three degrees:

(1) Simple, transient erythema;

(2) Superficial coagulation, disappearing in about fifteen days;

(3) Deep coagulation with a secondary eschar, repair of which may require three weeks or more.

The burns of this nature, produced by diathermy, have under proper measures, little tendency to become infected, and most often heal without leaving a visible scar.

(c) Deep burns are relatively rare, but may be of great gravity. They result by the use of too great dosage:

(1) In subjects with deficient sensitivity (see above);

(2) When the circulation is insufficient, as for example in a segment of an extremity.

These burns may reach the deepest layers (for example when the subject is spontaneously insensitive or as a consequence of anesthesia, as has been seen in patients undergoing operations), and produce extensive eschars. They may also, at narrow parts of an extremity, produce coagulation of the vessels with following dry gangrene of the distal segment of an extremity, which may necessitate an eventual amputation. In such cases we have to deal with accidents of grave prognosis.

Technic. According to every particular indication relative to the seat and nature of the affection established, we make an application every two days of about 20 minutes and allow in certain cases séances of 30 and even 40 minutes, but taking care to employ a less strong intensity. We gradually raise the intensity of the current to the limit of pleasant tolerance.

Which Apparatus Should Be Used? As we have already said, the high frequency currents, act:

(1) By thermic and analgesic effects.

(2) By electric effects.

(a) Appliances of damped waves yield a maximum thermic effect and electric actions. It is well that the latter are only little perceived, they manifesting themselves by electric

shocks possessing a sufficiently strong trophic effect. One will therefore advantageously use these apparatus in cirulatory disturbances (hyperemia, increased local metabolism); in muscular pains; in neuralgias, when the acute phase has passed, in the neuritides, but in this case with care in order not to relight the pains; in spasmodic affections; in inflammatory affections.

(b) The apparatus with sustained waves possess above all a thermic effect, the electrical effects being practically negligible. They are specially indicated in inflammatory and painful conditions.

(c) The appliances of short waves act essentially by a thermic effect, this being more marked than in the ordinary diathermic apparatus. Saidman gives to these thermic effects the name infradiathermy (supradiathermy. — Ed.), which Professor d'Arsonval considers a happy designation.

Experimental research has shown that if diathermy heats fat above all and thus permits only a poor distribution of energy in depth, the short waves on the other hand enabled a better distribution of caloric effect. Nevertheless one should not underrate the dangers of the intensity of the field, which experience has shown may be fatal to small animals in a short time.

The short waves are indicated as analgesics and eutrophics (algias, nephritides, trophic and cirulatory disturbances of poliomyelitis and of rheumatism, for example) as productors of artificial fever, and one knows the rôle they are called to play in general paralysis as a substitute of malaria therapy.

B. *Auto-Condensation Cage.* This requires powerful apparatus. The small solenoid is abolished and replaced by a sufficiently large one (joined to the two limits of the condenser) so that the patient can remain in the interior (whence the name "cage"). Without experiencing any sensation the patient finds himself subjected to the variations of the magnetic field and is subjected to the currents of Foucault.

C. *Condensation Bed.* As in the preceding case one must resort to powerful apparatus. The small solenoid is placed over the condensers, one of the extremities of this solenoid is attached to a metallic appliance (bar, handle, etc.), which the patients holds, the other extremity is connected with a large metallic electrode on which the patient rests, with a rubber covered mattress-plate between patient and electrode. In this manner a condenser is formed (metal plate, insulating matter or cushion) the two armatures of which sustain a series of charges and discharges.

The treatment with the condensation bed produces at first no sensation whatever. Nevertheless in the long run as a result of the successive changes and discharges, heat is produced, at first localized, later general and perceptible by the patient.

The physiologic properties of the high frequency currents employed in one or the other of the last two forms have been demonstrated by Professor d'Arsonval and Apostoli. Clinically one observes an amelioration of the general condition, increase in strenght, improvement of the circulation, betterment of the appetite and improvement of digestion and of sleep. From the physiologic point of view the number and excursion of respiratory phenomena are augmented (d'Arsonval); thermogenesis becomes more active (doubling almost the quantity of liberated heat) which results in greater activity of combustion and organic metabolism, (diseases of nutrition), urinary excretion is activated, the relation of uric acid to urea approaches the normal (Apostoli and Berlioz), there is a quantitative increase of urine, of urea, of total nitrogen, of phosphates, sulphates, chlorides, etc.

Finally, recent research has shown that in sympathicotonia these two modalities of the high frequency current produce a considerable lowering of the basal metabolism. All these effects appear to be more powerful with the condensation bed than with the autocondensation cage.

The effect on the circulation has been discussed extensively. Without here enumerating the different opinions advanced, we see the practical results one may attain by their use. The higher frequency currents do not modify calcification of the arteries (arteriosclerosis) and cannot lower the tension of subjects affected by constant hypertension. It is a fact just the same that they can be fruitfully utilized from a general point of view (d'Arsonval and Charrin), for, in detoxicating the organism, in ameliorating the peripheral circulation, they may in association with a dietetic régimen and hygienic measures bring about a perceptible improvement and delay the de-

velopment of these dreadful affections. Harmless as these two procedures of treatment may seem, it is proper to use caution in the beginning when one has to deal with certain forms of poorly compensated cardiopathy or with conditions of congestive nature.

Applications of Tension. These require the use of a resonator, that is, a metal wire coiled on itself (resonator of Oudin, spiral of Guilleminot, etc.), which serves to raise the tension of the high frequency current in a manner to obtain voltages equal with or superior to those of static. The current arising from the source of high frequency is closed on several spiral coils and the resonance produces in the rest of the apparatus tension currents greater than can be measured with the aid of a mobile cursor.

The resonator enables us to obtain effluves and sparks. These are (a) monopolar when the electrode is connected with the upper pole of the resonator, (b) bipolar, when the patient is at the same time connected with the lower pole.

Effluvation. When a patient is subjected to effluvation his entire body is traversed by very rapid oscillations to a point one can draw small sparks from any desired part of the body. Effluvation of high frequency produces effects analogous to those of static flow, that is to say analgesic and antispasmodic (painful phenomena of certain forms of neuralgia, hemorrhoids, etc.); antipruritic (dermatoses, pruritus, acute zoster, etc.); cicatrizing (painful anal fissures).

Effluvation is applied either by a glass or quartz tube of a more or less extensive vacuum (electrodes called MacIntyre), or by a metallic electrode covered by a glass mantle (condenser electrodes of Delherm, Oudin, Vignal, etc.).

The use of a resonance bath secures a powerful effluvation. To employ it one places the patient on an insulated stool. One of the extremities of the resonator is connected with a conductor held by the patient, the other is attached to an effluvial brush.

Surgical Application of High Frequency Current

Sparking. High frequency sparking is at once destructive and cicatrizing, as has been shown by Zimmern. In connection with surgical application, the effect of high frequency current results in the destruction of tissues. As with medical applications, the action may be divided into:

(1) Applications of quantity: diathermocoagulation, hot sparking;

(2) Applications of tension: fulguration;

(3) Electric knife (cutting effects.)

Diathermocoagulation, or *Applications of Quantity,* results from exceedingly localized application of diathermy and may be accomplished with all apparatus intended for medical diathermy, but there is no necessity for a very large dose. There exists in the so-called diathermy apparatus special limits intended for coagulation.

The object of diathermocoagulation is to destroy tissues by an excess of temperature. Properly applied it must bring the tissues to a temperature of coagulation, that is to say, about 70° C. The tissues then change color as the circulation is abolished. As a result there develops an eschar which disappears more or less rapidly depending on the depth of the coagulation.

Precautions. (1) The temperature of diathermocoagulation is insufficient to insure sterilization, it is therefore proper to take the usual precautions to insure sterility of the instruments which are used, which, in addition, should be free from defects.

(2) Before operating the intensity of the current should be regulated by testing the current through bringing the active electrodes close to a metallic plate.

(3) The current must not be allowed to pass until the active electrode is in contact with the lesion to be treated, and not to allow it to pass too long to prevent drying out of the tissues and their carbonization. Diathermocoagulation should, in fact, leave a soft eschar. Also one should not employ too great an intensity. A weak intensity prevents the adhesion of the tissues to the electrode and one can easily withdraw the latter.

(4) One has to deal with a painful procedure which may necessitate local anesthesia.

Technic. Numerous procedures are available for the attainment of diathermocoagulation:

(1) *The bipolar method with two electrodes,* that is, by the utilization of two electrodes of different sizes. The large — indifferent — electrode is placed at any desired point of the body (the closer it is to the site to be treated the greater the intensity), the small electrode

is the active one (of which there is an endless number of models).

(2) *The method by capacity,* in which the clothed patient rests on a large metallic surface which he touches only with his clothing which plays the rôle of a dielectric, while a small active electrode is employed as in the preceding case.

(3) *The bipolar method.* One utilizes two active electrodes of equal size (electrodes of double points for deep coagulation, as for example of the uterus; electrodes of two bulbs for superficial coagulation, separated electrodes, used in the treatment of angiomas; looped electrodes for pedicled growths, etc.). In this method the destruction is localized to the space between the two electrodes. The three procedures we have described facilitate energetic diathermocoagulation. If one desires less intense coagulation, we may resort to:

(1) *The unipolar method* of one wire which does not have an indifferent electrode. Only the small active electrode is used, which is attached to a single terminal of the apparatus. This procedure which provides only a weak coagulation, as for epilation, is almost painless, but requires powerful apparatus. It has the advantage of enabling the operator to select a good point of support, direct on the patient.

(2) *Diathermy without wire* (wireless diathermy). The patient is subjected to a diathermic current as, for example, by being placed on an autocondensation bed, and the procedure is accomplished by the physician making use of a non-insulated electrode, contrary to those in the preceding cases. Here, too, one obtains only a feeble coagulation and the operator can find a point of support on the patient if he places an insulating material between the patient and himself.

Results. It must be recalled that coagulation is always deeper than appears to be in the beginning. It is proper therefore to stop when the tissues have changed color, when the skin has become gray and the mucosa white. The coagulation finished, the patient is advised to avoid infection. As a general rule, the eschar disappears in about 12 to 15 days, leaving a perfect scar, more regular and less visible when the dosage has been weak, and if there has been no sparking.

Hot Sparking. For more localized destruction one may have recourse, to hot, carbonizing sparking, which is obtained by employing the bipolar methods, by capacity, or by the unipolar method, described above. In such cases the electrode should not be applied to the lesion. When the active electrode is 1 to 2 millimeters from the lesion the sparks are sprayed. Being very hot they destroy the surface (this is a practical procedure, provided only a weak intensity is used, to correct keloid scars, for example.) If the application lasts too long there will be carbonization and a hard eschar. As this procedure can be utilized in water it may serve to destroy neoplasms of the bladder (cystoscopic sparking).

Fulguration or cold sparking by means of *Applications of Tension.* This is a surgical application of high frequency apparatus equipped with a spark gap and an Oudin resonator. Special electrodes are used (glass tube with a central metallic conductor crossing the glass tube) which are connected with the high tension terminal of the apparatus. One obtains sparking by simply bringing near the skin the electrode which is caused to spray, and it is by manipulating the slide of the resonator that the effect may be modified. One may obtain:

(a) Short and thick sparks (relatively low voltage), which produces quick scarification of the tissues, cicatrization taking place rapidly and perfectly. It is here that fulguration finds a place in dermatology, as for the destruction of small cutaneous and mucous epitheliomas.

(b) Longer and less thick sparking is above all decongestive, revulsive, antipruritic (dermatoses, alopecia), cicatrizing (indolent ulcers, tuberculous ulcers, mal perforans), bactericidal (phagedemic sores, gonococcal ulcers of the cervix of the uterus, etc.). One may thus vary the effect of high frequency sparking according to the desired result and to the sensitiveness of the subject.

Electric Knife. We will only cite this application of high frequency currents, which is the domain of surgeons, by recalling that the electric knife, according to the conditions of its functioning enables the cutting of tissues with as well as without coagulation. One of its great advantages is the prevention of dissemination of neoplastic cells in operations for malignant tumors.

Conclusions

Professor d'Arsonval's labors have opened to science in general and to therapy in particular, new horizons which are far from com-

pletely explored. The name of d'Arsonval will remain among those great pioneers of science, who have shown the way to disciples of all nationalities who honor their master, and among whom we must not forget of the French school Oudin, Apostoli, Guilleminot, Zimmern, Bordier and his works on diathermy, Doumer, whose treatment of hemorrhoids by high frequency has become classic, Cluzet and his researches on the application of the high frequency currents in electrodiagnostics, and many others, all of whom we cannot cite, whose labors are universally known and esteemed.

D'ARSONVAL AND HIS WORK *

PROFESSOR HENRY BORDIER

Corresponding Member of the Academy of Medicine

LYONS, FRANCE

Whoever searches the depth of things finds that the scientific life of great men is characterized by a continuity of effort in the direction of the discovery of Truth. Their labors aim for one goal which is always the same; their researches, following the allurement of their first discoveries, are linked like a chain, to constitute a whole which redounds to the glory of the savants. It is thus that Pasteur left the study of mineralogy after his discovery of the polarization of tartaric acid and turned to bacteriology. It was the formation of moulds which developed in certain solutions of tartaric acid that led Pasteur to the study of the infinitesimal and eventually of microbes. As is known, the discoveries that resulted from his researches have made this great man illustrious in all domains of human activity.

Like Pasteur, d'Arsonval was guided in his researches by the study of a question which served as the point of departure for all his discoveries — the study of the physical, electrical and mechanical phenomena encountered in striated muscles. From every angle and around this axis of scientific direction d'Arsonval has made numerous discoveries which form like an enormous cluster a summit from which radiates the glory of the brilliant professor of the Collège de France.

To conduct to a good purpose the study of these very complex phenomena as well as all those which concern the tissues and living beings, required not only genius, but special gifts and a technical apprenticeship of great patience. This apprenticeship d'Arsonval served under another great master, Claude Bernard, whose preparator he was before he became his successor to the chair in the Collège de France. By his numerous discoveries — of which we will present a brief resumé — d'Arsonval became an innovator and an inspirer of a number of problems, which on first blush appear alien to each other. But when one makes a synthetic review of the master's work one notices that all his contributions to science are the outcome of his initial researches.

This diversity of his researches, though having the same origin, has caused men who are little familiar with his work to regard d'Arsonval now as physicist, now as physiologist, some time as an engineer, nay as a pure physician. We also see him successively as president of the Society of Electrotherapy, of the Society of Physics, of the Society of Electricians, of the Academy of Sciences, of the Society of Biology, as honorary member of the Society of Civil Engineers, etc.; without counting the great industrial societies that have had recourse to his varied knowledge and general culture so remote from the then honored specialization.

D'Arsonval has been the founder of *Biologic Physics and of Therapy by Physical Agents.* Before him, for forty or fifty years, instruction in physics in the faculties of medicine consisted of a brief repetition of that given candidates for the baccalaureate in the sciences. Thanks to d'Arsonval this instruction

* Translated from the French by a member of the editorial staff.

has undergone a radical reformation. Classical books turned the day and I am proud to have published in 1899 the first classic treatise on "Biologic Physics,"[1] which reflected d'Arsonval's ideas, adopted and taught particularly by Bergonié, whose pupil and assistant I have the honor to have been from 1886-1895. For the development of his researches it was necessary for d'Arsonval to create not only instruments of great sensitivity but also new methods, without which nothing could have been accomplished. The apparatus that were invented constitute an arsenal for his later labors in electrophysiology, thermogeny and calorimetry. Marey — who was familiar with the subject — has expatiated on the instruments contributed by d'Arsonval, which are considerable.

For the study of the electric phenomena of living tissues and particularly of muscle, d'Arsonval has invented *nonpolarizable electrodes* made from melted chloride of silver, which have become classic.

To determine the very feeble currents developed in the muscle, d'Arsonval constructed an instrument of great sensitivity, such as did not exist before. He had the ingenious idea of creating a galvanometer in which the circuit instead of being fixed, as in the old galvanometer, was mobile and placed in an intensely magnetic field. The *galvanometer of movable frame* represented an immense advance not only for electrophysiology but for the laboratories of pure physics and for the needs of industry.

The determination of the temperature of tissues, superficial as well as deep, which were made only with ordinary thermometers, attained, thanks to the *electrothermic appliances* of d'Arsonval, a precision of sensitiveness unknown before him, and it is due to him that we have *thermoelectric needles* and *sounds, comparative thermoelectricity, thermogalvanometry, etc.*

Inspired by the needs of his electrophysiological researches, d'Arsonval invented *microphones*, a *telephone* — the same that serves today as a receiver for telephony, wireless as well as commercial — a *voltmeter, coulombmeter, batteries (cells)* — appliances indispensable in the study of electric phenomena in living tissues. Finally in order to arrive at a knowledge of the secrets of animal thermogenesis, d'Arsonval had to contrive valuable *thermostats* which render such great service in laboratories of biology and bacteriology.

Having elaborated a whole series of highly ingenious instruments, d'Arsonval was armed to undertake first of all the investigation of an important physiologic problem, concerning the electric current proper of the muscle, both during function and at rest. If the function of the tissues liberate, according to conditions, heat, electricity, light, one knows since the discoveries by d'Arsonval, that the phenomena of nutrition, that is to say, life without function, produce constant galvanic electric currents whose transformation into calorific energy could be the principal cause of animal heat. In fact, one should note that the muscular currents which one obtains in the nonpolarizing electrodes represent only an infinite part of the currents of muscle. The latter are closed in themselves as continuous short circuits, and from that moment on they are perceptible to us only in the form of heat. The muscle, then, is an electric transformer of chemical energy rather than a thermic transformer, which becomes evident when one considers that the electric organ of the torpedo fish (electric eel) is an organ which actually is a modified muscle.

In the study of internal electric phenomena of muscle, the part which is due to d'Arsonval is great. He has discovered that while the current of a muscle at rest is the result of chemical activities, the current produced during the period of kinetic and dynamic activity of that muscle is due to a physical cause. Hypotheses have been presented previously to him to explain this current of muscular action, but d'Arsonval demonstrated by numerous experiments and by a complete analysis of the existing phenomena that the muscular current is properly explained by surface deformations and by variations of superficial tension at the level of the elements of striated muscle, in conformity with the laws discovered by Lippmann in the inorganic world. The conditions of Lippmann's experiment with water and mercury are found in striated muscle, and generally in all semi-fluid bodies of organic origin at the surface of mechanically deformable separation. This is what d'Arsonval has realized with his *artificial muscle* — a rubber tube divided by porous discs into a series of compartments containing mercury surmounted by acidulated water. If one stretches this tube

1. Collection Testut, Vol. I, 2nd edition.

between two hands holding the extreme ends, one feels a shock. The mechanical deformation has modified the electric tension. Moreover, one can change the current into physical motion by attaching one of the ends of the "mechanical muscle" to the middle of a diaphragm whose ends are connected with a telephone. The current of the telephone will produce in the appliance a reproduction of speech. In other words, the mechanical deformations, themselves weak and rapid, modify the electric tension, and reciprocally the variations of electric tension are accompanied by a mechanical deformation. These are the facts in physics which have enabled d'Arsonval to explain negative oscillation in the striated muscle.

This is the proper place to bring up among his ingenious experiments that of d'Arsonval's *telephonic muscle*. This consists of a muscle of a frog with its intact nerve. The nerve is excited by undulatory currents derived from a telephone or a microphone, before which one speaks. The tendon of the muscle is attached to the center of a membrane on which it pulls — a veritable cord (thread) telephone. When the membrane is auscultated by an acoustic tube one finds that the muscle reproduces voice tones to perfection.

It was but natural that d'Arsonval's investigations extended to the study of the *electric discharge of the torpedo fish*. His experiments led to the conclusion that the electric organ and striated muscle function in the same manner; namely, through variation of the superficial tension, but that these variations manifest themselves in the former by an electric current and in the latter by mechanical labor. From the point of view of energetics, current and labor are equivalent.

A celebrated experiment by d'Arsonval, which confirms the accuracy of his reasoning, is as follows: after having sectioned the nerves going to the electric organ of the torpedo, when one deforms that organ by mechanical means, one obtains an electric discharge. d'Arsonval's measurements have shown that the discharge of the torpedo fish can furnish a current up to 7 amperes at 300 volts, which is a power of more than 2,000 watts. All physiologists are in agreement with the idea so often confirmed by the master, "that muscle fundamentally is only an admirable transformer of energy, manifesting the most perfect laws of physics, of chemistry and of mechanics."

The experiments which I have just presented as a resumé should certainly suffice to render their author illustrious. But d'Arsonval's discoveries did not stop there. After having wrested from the muscle the secret of the mechanism of its electric currents proper, d'Arsonval sought to know the *effects of electricity* applied to muscles. It was well known that an electric current is capable of producing a reaction of muscles, but what was *not* known was that the electric energy produces a great activity of intracellular chemical transformations and as a consequence also of nutrition. His researches extended to the phenomena of muscular excitation, direct or indirect, by the electric current. It was known that this excitation produces a variable kinetic reaction according to whether the exciting current is the discharge of a condenser, the passage of a current from a cell or from a coil, or the current of an alternator. But there was neither system nor clarity in the study of these different mechanical manifestations of muscles. It is to the great credit of d'Arsonval that he has given us the idea of the *electric wave* and of the *characteristics of excitation*.

D'Arsonval was logically induced to produce an effect on the muscle by a difference of potential in sinusoidal form by utilizing an alternating current, the frequency of which he varied. For this purpose he devised apparatus and applicatory methods, the one's as ingenious as the others. By *progressively augmenting the frequency* he observed that tetanization of muscle took place up to a certain frequency. Above 5,000 excitations per second, muscular contraction no longer appeared, and as the frequency increased the organism ceased to react. While the *high frequency currents* affect neither the motor nor the sensory nerves, they equalized matters by activating nutrition. Elimination of carbonic acid is increased in great proportions and at the same time a large quantity of heat is produced, which rapidly results in more or less abundant transpiration. Again, while these currents with the identical tension and intensity have lightning-like effects at a low frequency, they were harmless and not even felt by the subjects through which they were passed. As d'Arsonval has stated at the time of his discovery, in 1892, it is with the electric vibrations as with light vibration, — the optic and acoustic

nerves cease to be impressed beyond certain limits.

It is essential in the interest of scientific truth to fix certain points regarding *the history* of d'Arsonval's *discovery* of these currents of such remarkable properties. It was in 1881, that the master of electrophysiology began to study the physiologic effects of the variable state of the electric current. After the study of the action on the muscles and nerves produced by a single wave, d'Arsonval naturally was led to employ waves which developed periodically. To increase the frequency of excitations d'Arsonval made use of an alternator without an iron core, capable of yielding up to 10,000 alternations per second. In order to exceed that number of excitations, d'Arsonval, in December, 1890, had the ingenious idea of making use of Hertz' oscillator, which made possible the attainment of alternations reaching up to several millions per second. At this number of excitations, the motor nerves and the muscles no longer react. It is important to state that d'Arsonval's discoveries of high frequency antedate the publication of the spectacular experiments by Tesla, of May 23, of the same year, which attracted the attention of scientists, nay of the general public, to the question of high frequency currents. It is well established that priority of the study of these currents belongs to the eminent French electrophysiologist.

Professor d'Arsonval did not pause in the evolution of his discoveries. Having found that the high frequency currents produced by Hertz' oscillator were of small intensity, he substituted for it the method announced a year later by Elihu Thomson, which was replaced by the following that merits consideration: two condensers (Leyden jars) were connected with the poles of a powerful Ruhmkorff coil, the other armature being attached to the terminals of a solenoid made of stout copper wire. The condensers discharged by means of a ball spark gap. The current whose physiologic effects he desired to study was secured at the helixes of the solenoid.

One recognizes exactly the arrangement which is used today in all appliances of diathermy, and it was at a meeting on April 20, 1892, that d'Arsonval published his experimental data. He showed that the current taken from the solenoid could brightly light a lamp of one ampere held between two persons placed in the same circuit. By substituting an alternator for the coil, d'Arsonval caused his body to be traversed by currents of more than three amperes without experiencing any other effect than a sensation of warmth at the wrists. The electric oscillations produced by this arrangement were damped, the sparks of the spark gap were long and relatively rare in consequence of the formations of continuous slightly noisy arcs.

Since 1892, d'Arsonval succeeded in securing undamped oscillations, for which he surrounded the spark gap, regulated to yield short sparks, with an electromagnet (choked sparks). Under the influence of an abundance of sparks, the oscillations of high frequency cease to be damped and become practically undamped; as a consequence one secures at the helixes of the solenoid a current of *diathermy. It is therefore brilliantly demonstrated that contrary to what was published at a certain time, it is to d'Arsonval that belongs the glory of having discovered the undamped oscillations producing diathermy.*

D'Arsonval has made other discoveries which it is interesting briefly to report at this time. He has invented an *electric chronometer* with which to measure the *speed of indirect excitation* through a nerve. He also could measure with that instrument the *duration of excitation* of muscles or nerves after death. This was followed by study of the *mechanism of death* by industrial electricity, which he has accurately understood from the beginning. As he has stated, there are two modes of perishing by lightning—atmospheric or industrial—: (1) by disorganization of the tissues, (2) by reflex action or inhibition. In the first case death by direct action is definite and there is nothing one can do; in the second case one may endeavor to resuscitate the electrocuted, success often justifying the efforts. One has been able to save *and one saves every day numbers of human lives* "by treating one struck by lightning or electrocuted like a drowned individual," as d'Arsonval was the first to teach. One sees here how much humanity owes to this great man!

D'Arsonval's studies always took place in disciplines which remained close to his initial researches. He has particularly sought to demonstrate the modification provided in animal thermogenesis by the action of high frequency currents, for which purpose he was compelled to invent ingenious *calorimeters* for animals as well as humans. For this chapter of biologic

physics he has created methods and technics of precision. Only by calorimetry is one able to determine the quantities of heat produced by fever and to gain deeper knowledge of the mechanism of pathologic thermogenesis. As a matter of fact the taking of the temperature of a patient during the febrile period does not inform us about the phenomena of thermogenesis. A patient may have either a peripheral or a central temperature higher than of another patient with fever without producing a larger quantity of heat, in calories, than that of the latter patient. Be this as it may, in calorimetry as in everything else, d'Arsonval showed a rare ingenuity and rendered here, too, immense services to physiology by furnishing solutions for theretofore unsolved problems. He was able to determine by his *calorimetric recorder* the influence of height, weight, condition of the skin, pressure, light, state of digestion and of radiation of the febrile state. He has furnished valuable information on calorific topography and on many other problems of physiology and biology. In the same order of ideas, d'Arsonval has studied the action of *low temperatures* on muscle and living tissues by utilizing as a source of refrigeration *liquid air,* which he himself manufactured in his laboratory. To conserve liquid air needed for his experiments, d'Arsonval invented the "Thermos" bottle. In his communication to the Society of Biology in the year 1888, d'Arsonval said: "This bottle consists of two glass vases, one placed in the other and joined to fashion one single vase. The interior is the container proper, and in the circular space one has produced a dry vacuum." It is therefore an error when one attributes the paternity of the "Thermos" bottle to J. Dewar, who appeared five years later, in 1893, and confined himself to the silvering of the exterior surface of the interior receptacle. The numerous demonstrations and lectures d'Arsonval gave on liquid air and its applications have created a number of vocations. The industry of artificial refrigeration owes much to d'Arsonval, who was one of the founders of the International Institute of Refrigeration.

One of the applications of the discovery of the *high frequency current* deserves to be recalled — as it is close to that of another physician-physicist, Professor Branly. I have reference to the production of waves utilized in radiotelegraphy and radiotelephony. When the station of wireless transmission of the Eiffel Tower was created it sufficed to take the material of d'Arsonval, such as was in possession of the manufacturer, and to carry it to the post of transmission. Doubtless, d'Arsonval has furnished nothing, so far as concerns the reception of the waves, beyond the principle of the ticker (sounder), but the sending material is his work. The wireless men owe — and they well know it — great appreciation to the physicists Hertz and Branly, but they also owe equally much to d'Arsonval.

The high frequency currents at first were composed of a train of damped or slightly damped waves. They become sustained ones, that is to say, of constant amplitude, if one employs a lamp of three electrodes to constitute an oscillating circuit. Among the remarkable qualities of the high frequency current we cite the following: If one places a subject in the axis of one large solenoid without any contact whatever, there arises a current which is actually created in the tissues of the subject.

The physiologic and therapeutic effects of these high frequency currents are most interesting. d'Arsonval has demonstrated the enormous quantity of heat developed by these currents not only on wires or on filaments of incandescent lamps, but also on animals whose paws, immersed in receptacles filled with water, sustained such a degree of coagulation that they became detached from the body a few days after the experiment. Bordier and Lecomte, on their part, while operating on rabbits, guinea pigs and rats, have been able since 1900 to produce almost immediate death of these animals as a result of the enormous quantity of heat developed by the passage of high frequency currents, as was done at that remarkable period by Professor d'Arsonval, who communicated their report to the Academy of Sciences. A few years later Zimmern and Turchini demonstrated the thermic effect of high frequency currents on human beings and dogs (*Arch.d 'Electr. Med.*, p. 675, 1908). But diathermy proper did not enter into medical practice until about 1910, a few years after the publications of Zeyneck, Bernd, Doyen, and Nagelschmidt.

By considerably augmenting the electric density at the level of one of the electrodes of very small diameter, the first experimenters showed that the coagulating effect of the tis-

sues was so intense that it was possible to utilize diathermy for various surgical applications; whence the name (though improper) of *electrocoagulation,* originally given to this kind of application by Doyen, in whose hands this new surgical method became very fruitful. Unfortunately he does not appear to have been followed in this new path by the French surgeons. An exception must be made for surgery of the genito-urinary apparatus, which has enabled the patients to benefit from the progress in diathermy.

In the medical applications of diathermy, the clinical researches of Laqueur and others showed that the diathermy currents inhibited the vitality of microbes infecting tissues and produced brilliant results in gonococcal arthritides. But it is not only in the affections of the joints that diathermy opens a new field of therapy. The number of affections in which this treatment is indicated is already large (see H. Bordier's *"Diathermie et Diathermotherapie."*)*

The place diathermy has achieved in the domain of physiotherapy is fully justified, for it is not solely by the calorific effects of the cells that its action manifests itself. There is among others the disturbance derived through the orientation of the ions and of particles in the colloidal state (ionoids) by the passage of electric oscillations.

Analyzing the phenomenon of high frequency, we find that if the frequency of oscillations is for example 500,000 per second, the duration of the electric current (whose intensity may attain up to 4,500 milliamperes) which passes the tissues at each alternation is one-millionth of a second. During this very brief period the ions and the ultramicroscopic particles (ionoids) endowed with electric charges, like the ions are being oriented in one sense and subjected to the beginning of a sharp propulsion when the current, in the contrary sense of alternation, is about to attract these ions and ionoids likewise during one-millionth of a second. There arises from this a sort of impulse which produces a profound disturbance in traversed tissues.

There is need now to account for, in the study of the physiologic and therapeutic effects of the high frequency currents and particularly of diathermy, with special regard to the elevation of temperature, of the action produced by the kinetic energy on the ions and on the electrified particles in colloidal suspension in the cellular protoplasm. The heat determined in the tissues subjected to diathermy, produces a hyperemia whose result manifests itself in the vital processes of the traversed cells. In a number of these cases, the cellular vitality fortunately may be enhanced by these oscillations. On the other hand certain pathologic cells show after the passage of diathermic currents important biochemic modifications, which may lead to the progressive elimination of these cells. This is the case in embryonal and neoplastic cells, which are not solely radiosensitive, but also thermosensitive, and therefore strongly affected by the diathermic currents. It is to their physicochemical state that, in my opinion, one must attribute these elective sensitivities, having reference to the colloidal state of the albumin in the cellular protoplasm.

Great as is the work of d'Arsonval, it is not entirely limited to his scientific productions. His moral and intellectual influence has been at once manifest and productive of good. In his school were pupils who in their turn became masters. Among them I will mention his favorite disciple, Georges Claude. This highly talented inventor has rendered the master a touching devotion, proofs of which one has often been able to read in his sensational publications. Let us recall that the idea of utilizing the tension of water of two different temperatures to produce turning of turbines is due as much to d'Arsonval as to Claude himself. The experiments of Georges Claude and Paul Boucherot with *the thermic energy of oceans* which, as is known, succeeded on a grand scale, are due to the suggestions of d'Arsonval.

The discoveries, the inventions and the successes which have led this great man to glory have left him indulgent and approachable — no one is more modest. "He has as much power of intelligence as grace of honor and of character," as H. de Varigny, one of his panegyrists, said of him. Character and quality of soul at the height of a great intelligence is indeed rare!

All who know the master can repeat the word Bergonié addressed to him on the occasion of his elevation to the dignity of Grand Officer of the Legion of Honor: "What a splendid man you are, and how we do love you."

* Ballière et Fils, publishers, Paris, 6th edition.

HIGH FREQUENCY AND BLOOD PRESSURE *

A. LAQUEUR, M.D.

Director of the Institute of Physical Therapy of Rudolph Virchow Krankenhaus.

BERLIN

The question whether it is possible objectively to affect high blood pressure by the high tension frequency current is as old as the method of d'Arsonvalization itself. From the very beginning the discussion of this question has taken an important place in the deliberations of the effect of high frequency. After d'Arsonval himself and a number of other French authors had taken an optimistic view about the influence on high blood pressure, a reaction set in, Loewy and Toby Cohn in Germany and Bergonié and others in France denying any effect, which they based on experiments. To be sure these experiments were made largely on animals and on *healthy* men, but the therapeutic results of high frequency therapy in pathologically increased blood pressure and especially in advanced arteriosclerosis, too, were doubted. I still remember how the well known French heart specialist, Huchard, at the Congress of Physical Therapy held in 1907 in Rome, thundered excitedly against exaggerations on this subject. Later the discussions assumed cooler forms, and of the authors who treated this problem in the German language we mention especially Bossart and Bühler of Zürich and Hiss of Gastein. They came to the conclusion that d'Arsonvalization, especially in the form of autoconduction in the solenoid cage, was capable not only of alleviating the subjective complaints but also of lowering objectively the blood pressure for a prolonged period in the presclerotic state and in high blood pressure produced by organic diseases of the cardio-vascular system, which has not yet become fixed. These authors at the same time frequently established an improvement of the heart action after treatment. It manifested itself by a stronger pulse with disappearance of irregularity.

Finally mention should be made of the contributions of the late physiologist Ernst Weber of Berlin. He showed that in cases of hypertrophy of the left ventricle in which examination of the plethysmogram revealed an excessive irritation of the vasoconstrictors after bodily toil, high frequency treatment was able to remove these states of irritation. These results are in accord with the findings by Bühler, who also attributes the effect of high frequency currents in hypertension to the circumstances that the accompanying *phenomena of irritation of the vasomotor system are overcome.*

These results at once provide a reply to the question whether it is at all purposive and useful to reduce the pressure in pathological hypertension by therapeutic measures. It also answers the problem whether harm can result from the lowering or removing of the increased blood pressure, as this increase is regarded at least partially as a *compensatory* phenomenon needed to maintain adequate circulation of the blood. So far as concerns *high frequency treatment,* the question of *harmfulness* must be *denied.* According to the experiences of the named authors and that of our own, d'Arsonalization is only capable of subduing irritations of the vasoconstrictors, which accompany the hypertension and even increase it. This state of irritation manifests itself by the well-known fact that in many cases of hypertension there is a certain inconstancy of the degree of pressure. The removal of this quasi-additional irritation is followed by improvement of the complaints caused by hypertension. But the influence of the high frequency currents is not strong enough to abolish the compensatory effect of the increased blood pressure. For this, measures would be needed which could produce a sort of collapse through excessive vasodilatation of the peripheral vessels, as, for example, by energetic procedures of sweating. Such effects certainly *cannot* be ascribed to d'Arsonvalization.

Our *own experience* with the application of d'Arsonvalization in the form of autoconduction in the solenoid gained during 25 years on a large number of patients, is generally in agreement with the above mentioned results.

* Translated from the original German by a member of the Editorial Staff.

To mention the *negative* side first, it is emphasized that in *fixed* hypertension, as it is especially seen in *nephrosclerosis*, it is *impossible* to produce a real reduction of the blood pressure, even by prolonged treatment. To be sure one frequently succeeds in alleviating the *subjective* symptoms (such as headache, tinnitus, sense of oppression) even in such cases for a short period. One can also see a slight lowering of the pressure *immediately* after each treatment, but this is transient, for one finds the original amount of blood pressure at the next séance. Accordingly autoconduction represents a therapeutic method which in nephrosclerosis and other forms of fixed hypertension (progressed arteriosclerosis, aortic insufficiency, aortic aneurysm) is harmless and capable of producing temporary alleviation, but which is devoid of *lasting* therapeutic effect.

The situation is different in the so-called *essential hypertonia*, in incipient arteriosclerosis and organic heart diseases, especially those of the myocardium, which show increased but not excessively high blood pressure, that is not over 200 millimeters Hg. and with a certain numerical *lability*. When in such cases complaints occur which are recognized to be related to high blood pressure, such as headache, congestions, sense of heat in the extremities, sense of oppression in the chest, etc., high frequency treatment in the solenoid or even on the autocondensation bed is indicated. One can observe with this therapy not only a diminution of the blood pressure after each single séance, which also shows a lowering of the difference between the maximum and minimum pressure, but there appears after a series of treatments also a *lasting reduction* of the pressure until finally a certain lower level is attained which remains permanently. In cases of blood pressure which in the beginning were not excessively high, the pressure may return to *normal* values. In exaggerated hypertonia (180 mm. and higher) it is as a rule impossible to reduce the pressure entirely to normal. The final pressure then amounts to 140-150 mm. At any rate one succeeds in suitable cases in attaining after a series of 10-15 treatments a more or less lasting reduction, which may extend to ¼-½ year and longer.

The two following examples illustrate what has been said. The tables concern patients treated in the office who kept at their occupations and received no other treatment, except d'Arsonvalization every other day. For the prolonged effect of any measure to reduce blood pressure observations on hospitalized patients are not conclusive, since the rest in bed alone may produce a considerable reduction of blood pressure. On the other hand the measurement of blood pressure before and after each *single treatment* may be well utilized also on hospital patients. Here, too, the observation is instructive that each single treatment produces an amelioration or disappearance of the complaints produced by hypertension in addition to the lowering of the blood pressure. In addition there are not a few hospital patients on whom the usual dietetic and medicinal treatment had remained without effect on the blood pressure, who were improved by one treatment by d'Arsonvalization. Whether or not this improvement will be associated with a prolonged reduction of blood pressure depends on whether one has to deal with the fixed blood pressure of nephrosclerosis or a still labile hypertension.

Whenever in a case of *apparently essential hypertension* treated in the office or hospital, substantial and lasting reduction of pressure does not take place, one must suspect the presence of a latent nephrosclerosis in process of development. When such patients are observed later, often years of palpable signs of grave nephrosclerosis can be demonstrated.

TABLE I

Arteriosclerosis. Treated from July 7 to July 27. Maximum Pressure.

7	VII	before	160	after 145
14	VII	before	148	after 135
16	VII	before	142	after 132
18	VII	before	135	after 125
22	VII	before	132	after 132
27	VII	before	132	after 125

This table shows that the influence of treatment becomes less as one approaches the normal.

TABLE II

Maximum and Minimum Pressure during a Course of 12 treatments between 20. X and 5. XI.

20.	X	195-100
24.	X	185-105
5.	XI	140- 85

TABLE III

Maximum and Minimum Pressure taken at different days of the course.

Mr. B. Essential Hypertension, d'Arsonvalization in solenoid.

24.	XI	170-105
29.	XI	150-100
4.	XII	140- 85
15.	XII	135- 90
19.	XII	before 135-85, after 125-85.

Mrs. St. Arteriosclerosis, d'Arsonval Solenoid

		Before	After
10.	XI	190-95	195-90
12.	XI	200-90	185-80
14.	XI	170-75	145-75
17.	XI	165-88	145-75
20.	XI	170-75	160-75
24.	XI	155-75	160-75
27.	XI	170-80	155-75

As already alluded to, the *manner of effect*

of the high frequency current in hypertension must be explained by a *sedative* influence, which here particularly affects the vasoconstrictors. Such a sedative influence manifests itself in d'Arsonvalization also in other indications, especially in the treatment of *painful conditions* and of *insomnia,* particularly of older persons with arteriosclerotic symptoms. The question whether toxic factors, which frequently cause vascular changes and increase of blood pressure, also are favorably influenced by high frequency treatment is not yet clearly answered. The experiments by the Americans, *Steele* and *Snow,* who found increase of the excretion of purin bases and of uric acid after prolonged high frequency therapy, speak for such an influence.

Reduction of blood pressure may also be produced by a *direct* application of the high frequency currents to the anterior thorax wall by means of a condensation electrode similarly to that of d'Arsonvalization, provided strong discharges of sparks are avoided, and only such patients are selected in whom the hypertension is not too pronounced. Patients with a pressure of about more than 180 mm. often poorly tolerate direct treatment. On the whole this method lacks the advantage of autocondensation — complete harmlessness. A contraindication to autoconduction itself exists only occasionally, when the hypertension is accompanied by intense *nervous hyperexcitability.*

It has been claimed that the effect of d'Arsonvalization on the blood pressure is not caused by the electric current itself but by the *inhalation* of combustion gases which are developed during the jumping of the sparks in the spark gap. This theory by Peemöller has a justification insofar as air ionized through the sparks actually contains elements which on inhalation have a lowering effect on the blood pressure. According to Peemöller and other investigators it is above everything else nitrous oxide (N_2O) which produces such an effect.

But in the usual technic of d'Arsonvalization, according to our experiments, the inhalation of these gases plays no rôle in the reduction of blood pressure. As is shown in the accompanying table, reduction of blood pressure takes place only when the solenoid cage actually is connected with the electric oscillation circuit. If this contact is *interrupted* our experiments show that reduction of the blood pressure is not affected, in spite of the continuation of the function of the spark gap, of which the patient had no knowledge.

TABLE IV

Solenoid Treatment (d'Arsonval) with and without contact of the cage to the high frequency apparatus.
Mrs. H. Hypertension. Tinnitus.

		Before	After
13.	XII	160-90	148-94 with contact of the cage.
15.	XII	144-86	136-86 with contact of the cage.
18.	XII	146-84	138-84 with contact of the cage.
21.	XII	140-80	148-80 without contact of the cage.
		148-80	132-80 with contact of the cage.
22.	XII	140-80	130-85 with contact of the cage.
27.	XII	145-78	142-76 without contact of the cage.
		142-76	130-80 with contact of the cage.
29.	XII	140-95	130-95 with contact of the cage.

But one observed an increase in the reduction of blood pressure when the patients were made to inhale the air in their proximity which had been ionized through the high frequency discharges. For such experiments we made use of a so-called ozonizing apparatus,[1] such as is employed to purify the air in badly ventilated rooms. By it the development of ozone, or the ionization of the air takes place not at all by the spark gap but by the spark discharges in the secondary circuit of oscillations of a small high frequency apparatus. A small ventilator attached to the apparatus distributes the ionized air in the vicinity. If the patient is made to inhale this ionized air about 5-10 minutes, reduction of blood pressure similar to that following d'Arsonvalization may take place. After a series of such séances one also sees lasting effects, but according to our experience the effect is *not so regular* as after the application of d'Arsonvalization in the solenoid cage. It also happens that sensitive patients tolerate the inhalation poorly and then do not react to the treatment by lessening of the blood pressure.

The following table is presented to substantiate the similarity between the effect of the inhalation of ozone and of the high frequency treatment in the solenoid. Both treatments have been given the same patients at different days. The last table shows that in *fixed* blood pressure in cases of nephrosclerosis the lowering effect of inhalation of ionized air has the same transient character as that of d'Arsonvalization.

As is known, the air may be ionized not only by high frequency sparks but also by light rays, especially by *ultraviolet rays.* Air ionized in this way, too, lessens blood pressure by in-

(1) Radiologie, Berlin W. 35.

TABLE V

Inhalation of Ozone and Solenoid Treatment

	Mrs. R. Inhalation			Solenoid	
	Before	After		Before	After
I	205-135	190-105	II	185-110	175-125
III	165-105	140- 95			
IV	155-115	125- 95			

Two Weeks After Completion of the Course, 165-95

	Mrs. K. Inhalation		Solenoid	
	Before	After	Before	After
18. XII	193-55	175-80		
19. XII	190-55	155-80		
21. XII	155-8			
22. XII			165-60	155-60
23. XII			165-60	165-60
28. XII	155-60			
29. XII	165-75			

TABLE VI

Inhalation of Ozone

1. Slight and Transient Effect in Nephrosclerosis

		Before	After
21.	I	205-110	195-105
22.	I	200-110	195-105
23.	I	205-110	195-105

2. Stronger Individual Effect in Nephrosclerosis

Before	After
195-125	175-120

halation. One can increase this effect by inhalation in a *closed chamber* in which two quartz lamps are burning. We have treated patients with hypertension in such a chamber, constructed according to the data by Picard, and also have noted reduction of blood pressure. On account of the very strong development of ozone in the small, closed space, such experiments can be made only for a short period under great measures of precaution.

The therapeutic application of *ionized air* for the special purpose of influencing hypertension and its accompanying disturbances has of late years received great attention in Germany. This was due to the report of Strasburger, Dessauer and Happel at the International Congress of Physical Therapy held in Liège in 1930, on a method by which one succeeds in charging the air to be inhaled either with purely positive or with purely negative ions. The air charged with positive ions is hardly tolerated and produces complaints of different sorts. Strasburger and Happel have attained noteworthy results after inhalation of negatively ionized air, consisting of subjective and objective improvement of hypertension and its associated complaints. Even in such patients who did not react to the inhalation of negative ions by lowered blood pressure, frequently symptoms could be removed which are attributable to hypertension, e. g., headache and migraine.

We cannot here enter into a detailed discussion of the theoretic conclusions which follow these interesting experiments. They give important hints on the effect of climate of various regions on health, and on the therapeutic influence on disturbances due to change of climate.

We, ourselves, have not as yet worked with the Dessauer apparatus, which is very expensive. But we are at present engaged in experiments by which the air of a room is ionized in a different manner, and preferably though not exclusively is charged with negative ions. The principle of the procedure is based on the fact that the negative electricity of a static machine is utilized to charge a water spray whose droplets fill the air of the treatment room. Dr. Helfgott will publish a detailed report of our results at a later date. For the present it can be said that patients with high blood pressure as a rule experience pronounced relief after inhalation of negatively charged air and that in cases in which the pressure is not fixed, a reduction of the pressure can be seen after each treatment. But it must be expressly emphasized that here, too, a few of these patients have experienced a *better* subjective and objective reaction to *d'Arsonvalization* in the solenoid.

Finally *diathermy* must be added to the physical methods which are employed in the struggle against hypertension. For this purpose it is employed either as general diathermy on the condensation bed or as general heating of the body in another manner. Often it suffices to heat the lower extremities. Finally heating of the thorax alone can have a lowering effect on blood pressure. But the effect of all these methods is *neither so regular* nor so *certain* as that of d'Arsonvalization in the form of autoconduction. There also are certain contraindications to diathermy in grave diseases of the myocardium. We have found very satisfactory a *combination* of diathermy with d'Arsonvalization in cases of hypertension. In this method we apply diathermy to the lower extremities for 10-15 minutes and follow with autoconduction in the solenoid cage for 8-10 minutes.

Summary

It may be said, that physical therapy commands a number of methods capable of overcoming the complaints produced by hypertension and of reducing blood pressure. But

when one compares these methods with each other, it is found that even today d'Arsonvalization still occupies the first place, because of the relative certainty of its effect and harmlessness to the patient. The genial initial of high frequency therapy has therefore in the course of time proved that he was right when, almost forty years ago, he recommended his method also in the struggle with the affections of high blood pressure.

THE LANDMARKS OF ELECTROTHERAPY

W. J. TURRELL, A.M., M.D.

OXFORD, ENGLAND

The development of electrotherapy may be divided into definite periods, originating from the discovery of new methods of treatment of disease by electrical energy. These periods form distinct milestones in the history of medical science, whose main landmarks may be outlined as follows:

(1) The therapeutic application of the high voltage currents of low milliamperage derived from the frictional machine by Kratzenstein, 1744.

(2) The medical application of the constant or galvanic current by Galvani, 1791.

(3) The discovery of the induced current by Faraday, 1831, and its application to medicine by Golding Bird, 1836, and Duchenne, 1849.

(4) The discovery of the high frequency currents by d'Arsonval, 1888-1890.

Four names, therefore, stand forth preeminently in the history of electrical treatment: Kratzenstein, Galvani, Faraday, and d'Arsonval.

Let us consider the work of these pioneers and its influence on the development of electrotherapy.

Christian Gottlieb Kratzenstein was born at Wernigerode, of which town his father was burgomaster, in 1723. He studied in Halle, and whilst there wrote, in the year 1745, the first book on electrotherapy, *Abhandlung von dem Nutzen der Electricität in der Arzneiwissenschaft*. He was evidently a man of wide scientific attainments for he was successively professor of physics at Halle, in 1747, professor of mechanics at St. Petersbrug, in 1749, dealing there also with astronomy and nautical problems, and professor of experimental physics at Copenhagen, in 1753. At Copenhagen he was appointed by the King of Denmark to study the effects of electricity on disease. In addition to his other work, he delivered popular lectures, wrote to the lay press, and advertised for patients. It is therefore not surprising that his fellow professors regarded him as "a vulgar, pushing fellow."

Kratzenstein's method of electrical treatment was by means of a large revolving glass globe, the patient being insulated on a wooden stool. He applied sparks to his patients who owing to insufficient insulation, experienced pain in their toes. Kratzenstein claimed that the most minute parts of the organism were shaken by electricity.

It is not infrequent in the history of any science that pioneers vaguely foreshadow future theories. This is the case with Kratzenstein when he attributes the action of electricity to the shaking or disturbance of the most minute parts of the organism. The origin of this idea is indeed far earlier than the work of Kratzenstein, for it is outlined in the writings of Lucretius:

"Again, a blow more severe than its nature can endure, prostrates at once any living thing and goes on to stun all the senses of body and mind. For the positions of the first beginnings are broken up and the vital motions entirely stopped, until the matter, disordered by the shock through the whole frame, unties from the body the vital fastening of the soul and scatters it abroad and forces it through all the pores. For what more can we suppose the infliction of a blow can do, than shake from their place and break up the union of the several elements? Often, too, when the blow is inflicted with less violence, the remaining vital forces are wont to prevail, aye, prevail and still the huge disorders caused by the blow and recall each part into its

proper channels and shake off the motion of death now reigning, as it were, paramount in the body, and kindle afresh the almost lost senses."

Such a theory is very attractive, but its adoption in the past has frequently given rise to the most erroneous assumptions. For example, in the Abram box and in the fraudulent war hoax of Shearer we trace the misleading application of this principle. Notwithstanding the setbacks this theory has sustained from such misapplications, it again and again recurs when we attempt to arrive at the basic action of electricity as a curative agent. As Professor Bigelow says: "What we observe and measure is always exclusively heat, light, and electricity. These are essentially the same thing, vibrations, only differing in wave length. They may then be considered as one form of energy. We reach an astonishingly simple result. All we observe is energy. All energy is motion."

The "ictus" or blow of Lucretius comprises the arrest, absorption, or transformation of this kinetic energy. It is the arrest of the electrical energy by the anti-cathode of the electrons hurled forth with tremendous force from the cathode that gives rise to the x-rays. It is the arrest of the electrical energy emitted from the carbon negative pole, when it impinges upon the tungsten positive pole, that, in the tungsten arc, gives rise to the characteristic wave length which we term ultraviolet radiation. The passage of powerful vibrations through water will kill fish and other forms of life, whether these vibrations are of the supersonic wave length (50,000 volts, 300,000 frequency, Wood and Loumis), or of the ultrashort frequencies from the apparatus of Bedouin (30,000,000 frequency, Bordier). In neither of these cases is the temperature of the water sufficiently raised to account for the death of the fish.

There is much clinical as well as this physical evidence to justify the belief, now held by such leading authorities as d'Arsonval, Bordier, and others, that the vibratory action of the high frequency currents has a therapeutic effect apart from that of heat alone.

Frictional electricity was utilized by several other workers shortly after and independently of Kratzenstein's researches. Among the writers upon this subject at that time were the eminent divine, John Wesley, and the notorious revolutionist, Jean Paul Marat. The books on electrotherapy of both these authors (*The Desideratum*, 1780, John Wesley; and the *Memoires sur l'électricité médicale*, 1784, J. P. Murat), will well repay careful perusal, both on account of their historical interest and the side-lights they shed upon the characters of their famous authors.

Luigi Galvani (1737-1798). The first paper in the handwriting of Galvani relating to the excitation by electricity of muscular contraction in the leg of a frog, was dated November 6th, 1780; a subsequent paper, dated September 20th, 1786, entitled, "Electricity of Metals," was also found among his writings.

The work of Galvani was anticipated more than 100 years by the researches of the celebrated entomologist Swammerdam, who, in a paper entitled, "A Treatise on the Electrophysiological Phenomena of Animals," describes the following experiment which he demonstrated to the Grand Duke of Tuscany, in 1678. "Into a cylindrical tube of glass was placed a muscle, the nerve of which was enveloped with a small silver wire, in such a manner that it could be raised without injury. The first wire was brought through a ring, bored in the extremity of a small copper support, soldered to a sort of piston or partition; but this small silver wire was disposed of in such a manner that, on passing between the glass and the piston, the nerve could be drawn by the hand so as to touch the copper. The muscle immediately contracted."

Galvani's magnum opus, *De viribus electricitatis in musculari commentarius*, was published in 1791, and is divided into three parts: artificial, atmospheric, and animal electricity.

Galvani was at first led to believe that the electricity came directly from the muscles and nerves, and in the flush of his initial success is stated to have claimed that he had discovered the origin of life. Alessandro Volta (1745-1827), however, showed that the current came from the contact of two dissimilar metals.

Probably as the result of Galvani's belief that he had discovered the origin of life, the idea arose that by means of the galvanic current the dead could be restored to life and the blind to sight. As the natural outcome of such unwarranted conclusions, the immediate impetus to electrical treatment was of a very sensational character.

The scientific methods of Michael Faraday

were of a far different character than those of Galvani, and the great discovery of the principle of induction by the former, in 1831, was attended by far less sensational but more valuable clinical results than those which immediately ensued upon the publication of Galvani's work.

Faraday was actuated by the true principles of pure science throughout the whole of his career, and he was influenced by no other motive than that of ascertaining the truth. As the outcome of his work the effects on electrotherapy have been in their special way as striking and as fruitful as have been the results obtained in the other branches of physical science that his discoveries have developed and so greatly enriched.

It is to Dr. Golding Bird of Guy's Hospital, that we owe the first published account of the application in medicine of Faraday's induced current. In the history of electrotherapy full appreciation has not hitherto been accorded the pioneer work of this distinguished physician.

The lectures which Dr. Bird delivered, in 1847, before the Royal College of Physicians were scholarly and critical and of a more scientific nature than many of the modern treatises on electrotherapy. The problems and difficulties which he encountered were very similar to those with which we are so often faced today. They cannot be better expressed than in the words of Dr. Bird:

"Electricity has been by no means fairly treated as a therapeutical agent; for it has either been exclusively referred to, when all other remedies have failed — in fact, often exclusively, or nearly so, in hopeless cases — or its administration has been carelessly directed, and the mandate, 'Let the patient be electrified,' merely given, without reference to the manner, form, or mode, of the remedy being for an instant taken into consideration. Conscientiously convinced that the agent in question in a no less energetic than valuable remedy in the treatment of disease, I feel most anxious to impress its employment upon the practical physician, and to urge him to have recourse to it as a rational but fallible remedy, and not to regard it as one capable of effecting impossibilities."

Dr. Golding Bird appears to have made a convert of his famous hospital colleague, Dr. Addison, who in the Guy's Hospital Reports, October, 1837, writes as follows:

"As a last resource, I determined on giving electricity a trial. I was, perhaps, in some measure induced to do so in consequence of having an opportunity of securing the assistance of Mr. Golding Bird in its application. The effects produced by it at once gratified and surprised me, and led to further trials, the results and particulars of which will not, I trust, be deemed altogether unworthy of the attention of the profession. . . . It is, nevertheless, much to be feared that many persons, like myself, have been led greatly to underrate its efficacy, either in consequence of its vague and indiscriminate recommendation, or from the inefficient and careless manner in which it has been applied."

Dr. Golding Bird's work was followed shortly by the publication of Duchenne, of Boulogne, of his application of Faraday's principle of induction to physiology, pathology, and therapeutics (*A Critical Examination of the Instruments of Induction,* Duchenne, 1852).

Of the physiological and therapeutic value of the induced current, Duchenne wrote as follows: "Of the three forms of electricity, induced electricity (faradism) is the best for muscular electrization, especially as it can be practiced frequently and for a long time. . . . In its application to physiology, pathology, and to treatment, this method of electrization has surpassed my expectations in yielding scientific and practical results of the highest importance."

The title of "The Father of Electrotherapy" has been bestowed upon Duchenne by French electrotherapists, although the bestowal of this honor upon him is not historically justified, but certainly pardonable when we consider the immense value of Duchenne's work in the foundation of neuropathology, and the stimulus it gave to the researches of the early French electrotherapists to whom our specialty is so greatly indebted.

The development of electrotherapy has not been one of steady and uninterrupted progress: landslides, as well as landmarks, have characterized its evolution. Perhaps it was inevitable that, in the early development of electrical treatment, attempts should be made to reconcile its theories and adapt its methods to the treatment by drugs.

Priestley, writing in 1775, thus alludes to the results attending this method of compromise by the electrical introduction of drugs:

"In the course of history, we have frequently seen frequent instances of self-deception, for want of persons attending to all the essential circumstances of facts; but nothing that we have seen equals what was exhibited in the years 1747 and 1748. Mr. Grey's deception was chiefly due to his mistaking the cause of real appearances; but in this case we can hardly help thinking that not

only the imagination and judgment, but even all the external senses of philosophers must have been imposed upon. It was asserted by Mr. Privati, of Venice, (who has all the merit of these extraordinary discoveries), and, after him, by Mr. Verratti, at Bologna, Mr. Bianchi, at Turin, and Mr. Winckler, at Leipsic, that if odorous substances were confined in glass vessels, and the vessels excited, the odors and the other medicinal virtues would transpire through the glass, infect the atmosphere of the conductor, and communicate the virtue to all persons in contact with it; also that those substances held in the hands of persons electrified, would communicate their virtues to them; so that medicines might be made to operate without being taken into the stomach. . . . They even pretend to have wrought many cures by the help of electricity applied in this way."

In 1858, Sir Benjamin Ward Richardson reintroduced, under the title of voltaic narcotism, this principle of the electrical introduction of drugs by means of the constant current. He subsequently, however, withdrew the claims that he had made for the practical value of this method.

In comparatively recent years a similar method was reintroduced under the name of Ionic Medication. In the formation and application of their theories the advocates of this method entirely overlooked the principles of the polar and interpolar action of the constant current, which were so clearly laid down by Faraday, and have retreated trench by trench to their last line of defense as they have been assailed by experimental and clinical research. In the track of their retreat they have left a legacy of the gross misapplication of such terms as Ionization, Cataphoresis, Iontophoresis, etc., and this has served to obscure the true action of the constant current and has become almost the despair of the exact worker.

It is a relief to turn from the setback occasioned by such erroneous views to the great work of d'Arsonval in his discovery of the high frequency currents. Like Faraday, d'Arsonval was engaged in purely scientific research. He had no knowledge and no vision of the high frequency currents to obsess his mind or obscure his judgment.

All historians will probably agree that the best method of avoiding error in recording discoveries in their correct chronological order is to consult the original writings of the discoverer. For this reason, and also because other writers will deal in greater detail with the outcome of d'Arsonval's discovery, I will base my remarks upon d'Arsonval's original paper, *Action physiologique des courants alternatifs à Grande Frequence,* in Archives de Physiologie Normale, 1893.

From this paper it would appear that d'Arsonval, in 1888, whilst investigating the physiological action of alternating and sinusoidal currents, found that by increasing the number of interruptions or waves administered in tetanizing a muscle, the intensity of the phenomenon of excitation was correspondingly increased, until a maximum of 2,500 to 5,000 excitations a second was reached: after this point an increase in the frequency caused a decrease in the degree of excitation. The apparatus available at that time was not capable of producing more than 10,000 excitations a second. In December, 1890, d'Arsonval by employing the wireless apparatus of Hertz obtained "billions of electrical excitations a second," and was thus enabled to suppress all muscular contraction and sensation, and hence he was the first to demonstrate the characteristic clinical phenomena of high frequency currents. D'Arsonval stated that he passed 3 amperes through his body without any appreciable effect other than "a little heat at the entrance and exit of the current." In his lectures at the Societé de Biologie," in 1891, he suggested two hypotheses in explanation of the absence of excitation.

(1) That owing to their enormous frequency these currents pass exclusively on the surface of the body.

(2) That both the sensory and motor nerves of the body respond only to a certain definite frequency.

D'Arsonval rejected the first of these hypotheses by pointing out — and it was an original observation of great importance — that high frequency currents, which in the case of metallic conductors are confined solely to the surface of the metal, in the case of the human body actually penetrate through the organism. D'Arsonval at that time favored Brown-Sequard's theory of "inhibition" as the correct explanation of the phenomenon. The modern view appears to be that these very rapid oscillations do not admit of the electrochemical effect of one polar phase becoming effective before its action is annulled by the rapidly recurring neutralization of the opposite phase and vice versa.

It has been recently stated that d'Arsonval observed the heating of the tissues, but did not

realize its importance. The injustice and inaccuracy of this statement is clearly shown by the concluding passage in d'Arsonval's original paper, in 1893:

"The results that I have briefly pointed out, and those that I have already obtained clinically, lead me to hope that we now possess in the different modalities of electrical energy considerable therapeutic resources. For many years past I have studied the action of physical agents on the phenomena of life, and I hope that these experiments may serve to show objectively that the alliance of physical agents and physiology today permit of the formation, under the name of Biophysics, of an entirely autonomous science."

Although the nature of the high frequency currents was presented so clearly and in such a scientific manner by d'Arsonval, the somewhat sensational upheaval, which these currents occasioned on the pre-existing ideas of the stimulating and excitatory character of electrical currents, gave rise to an unjustifiable exploitation of his discoveries by workers who had no conception of the principles governing the currents.

A temporary setback, such as so frequently follows new discoveries, when they are ignorantly and improperly applied, ensued; and the high frequency currents in consequence for a time were regarded as a form of high finance by means of which shekels could be extracted from the pockets of a gullible public.

The remarkably complete and well-planned book, *Lehrbuch der Diathermie,* 1913, by F. Nagelschmidt, did much to remove this impression and to place diathermy on a sound scientific and clinical basis. Diathermy, indeed, has been exceptionably fortunate in its literature. For in the later work, *Diathermie et Diathermotherapie,* by H. Bordier, we have a monograph, now in its sixth edition, which serves as a model for this type of literature, dealing in a scientific, impartial, and critical manner with the physical, physiological, and clinical aspects of diathermy. So great, indeed, has been the success of d'Arsonval's work, aided by the publications of Nagelschmidt and Bordier, that at the present time it is tending to throw undeservedly into the background many of the older, valuable forms of electrical treatment. The only remedy for this, and the only means by which a just and lasting perspective can be obtained of the relative value of the various electrical methods, is the inclusion of electrotherapy in a well-planned schedule of the examining boards for medical students.

Such a reform is long overdue and it should be the endeavor of all interested in the development of electrical treatment to bring it about as speedily as possible. Otherwise, not only electrotherapy, but also the whole science of medicine will suffer.

In conclusion, I am convinced that every electrotherapist will associate himself with me in expressing our very high appreciation of Professor d'Arsonval's epochal discoveries and in acknowledging the great debt we owe him for the influence which his researches have exercised on the development of our science.

THE PRESENT STATUS OF ELECTROPYREXIA *

CLARENCE A. NEYMANN, M.D., S. M. FEINBERG, M.D.,
D. E. MARKSON, M.D., S. L. OSBORNE, B.P.E.

CHICAGO

In spite of the fact that so little time has elapsed since the inception of hyperpyrexia, this type of therapy has become so increasingly popular that a review of the methods and results of the various workers and of our own group is perhaps opportune. Electropyrexia was first employed in the treatment of disease by two of us. Our preliminary report[1] in 1929 outlined a technic for the production of artificial fever in man and animals. Later articles[2], [3], [4], [5], [6], [7], [8] amplified this. A review may serve the purpose of correlating and thus assist those who have entered or are about to enter the field.

Human thought, activity and progress seem surprisingly disjointed and unconsolidated. Often several generations elapse before an idea or theory crystallizes into action and even then there is usually a backward flow of the tide, induced by those who are habitually antagonistic to innovations. Let us turn back the pages of history for a moment and examine a related subject. It is now a well-known fact that fever of comparatively short duration can be produced by hot baths and that this therapy is of definite value in the treatment of disease. The ancients used such baths for precisely this purpose. Elaborate bath palaces were constructed by the Greeks and Romans not only for bodily hygiene and amusement but also for the therapeutic benefits. In medieval Japan and Java intensely hot baths were and are still used for their curative properties.[9] Many conditions which are now definitely known to be benefited by hyperpyrexia, have been and are being successfully treated at these thermal springs. Finally numerous semi-civilized and barbarous tribes used steam and hot water baths to such an extent that they were incorporated in their religious rituals for frightening and banishing the demons of disease.

In 1883, Philipps[10] clearly demonstrated and reported the fact that fever could be induced in man by means of hot baths. This form of artificial hyperpyrexia was rediscovered and applied to animal experimentation by Weichbrodt and Jahnel[11] in 1919, again described and advocated for the treatment of human syphilis by Schamberg[12] in 1927, studied by Walinski[13] in 1928, reapplied by Rosanoff[14] in the same year, and finally clarified by Mehrtens and Pouppirt[15] in 1929. Thus it took forty-six years to arrive at a practical therapeutic goal. Most of these authors evolved their theories independently.

It is therefore not a total surprise to us whenever we hear of so-called new methods of hyperpyrexia, new indeed to the authors, who evidently have not studied the rather voluminous literature, and honestly believe they have made a great discovery. Excluding the above mentioned results with hot baths, fever may be induced in man by external heat or penetrating heat. Both types use electricity as a source of power. External electrical heat was first applied by Kahler and Knollmeyer[16] in 1929, who used an ordinary electric light cabinet. They did not attempt to maintain the fever for any great length of time. Penetrating heat in the form of high frequency current was first employed by us when we began our initial experiments.

It is evident that the application of these two modulated forms of energy must cause very different physiologic results. During the past eighteen months, one of our problems has been to clarify this question and to decide under what conditions either form of energy is most suitable for therapeutic purposes. To the category of external dry heat belong such methods as the electric blanket, the electric light cabinet, or one of its modifications, and apparatus recently advocated by manufacturers, which depend on infrared rays. To the class of penetrat-

* From the departments of neuropsychiatry, internal medicine and physical medicine of Northwestern University Medical School and the Cook County Hospital, Chicago, Illinois.

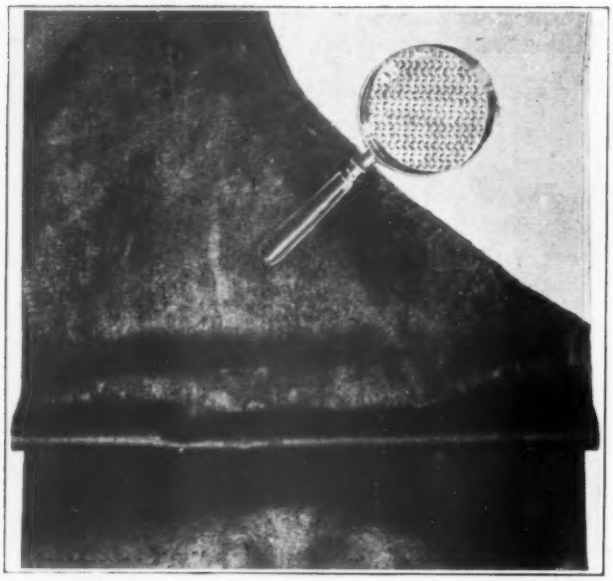

Fig. 1. Section of vulcanized rubber electric blanket, part of rubber covering removed, fabric element exposed and enlarged showing internal construction. Wires are of copper alloy size 36, stranded 28, to the cable with double cotton insulation spaced ½ inch apart and woven into the fabric so that no two wires can touch and produce short circuits.

ing heating agents belong the diathermic methods, the radiotherm and those appliances which partly use these methods and partly external heat. Examples of the latter are radiotherms combined with electric hot air blowers for the purpose of keeping the patient dry and surrounding him with an atmosphere of hot air,[17] and diathermic machines built into hot air and electric light cabinets.[18], [19] All these methods will produce artificial fever of any desired degree. Let us now consider this fever from the physiologic standpoint.

From the angle of simplicity and economy, external heat is evidently the best method of producing fever. However, simplicity and economy are not always the things we most desire in a method which involves life and health. Before the work of Wilgus and Lurie[20] was begun, we were well aware of the possibility of producing fever by means of the electric blanket, but were too occupied in perfecting our diathermic technic to consider this matter, especially since we were also aware of severe burns often produced by this method.

At first the original and usual type of blanket was also employed by us. It is a dangerous equipment. It consists of many noninsulated or partially insulated wires woven into a cloth and covered with other absorbent materials. During the treatment free perspiration, a good conductor, seeps into the blanket which is wrapped around the patient. Short circuits result. The blanket catches fire and the patient is cooked in his own fluid. We are glad to report that we did not electrocute any one with this appliance, though we did produce burns two inches deep and a foot in diameter. Evidently a blanket which is not absolutely moisture proof is totally unsuited for the purpose of hyperpyrexia.

A new blanket which will shortly appear on the market was therefore evolved. The wires of this device have enough tensile strength to resist breakage for many months; they are vulcanized into pure gum rubber and the temperature of the instrument can be controlled by a rheostat. This new blanket promises to be a very useable appliance. Fig 1 illustrates its internal construction. Electric light cabinets and cabinets using infrared rays are still in the experimental stage and are being used and investigated by us.

What do we really wish to accomplish by means of a fever machine? Evidently we desire the utmost safety of the patient, a method which is as fool proof as possible from the standpoint of burns, which will allow of a proper dosage, and finally, one which will raise the temperature quickly and maintain it as long as possible without

undue hardship and suffering. As will be shown later on, various degrees of heat seem best suited to the treatment of different diseases. Whenever we desire long sustained temperatures, it is important to reach therapeutic fever levels as soon as possible. Long sustained temperatures seem to us to be the most potent procedures. By long sustained fever we mean a continuous temperature above 103.5° F. lasting between eight and ten or even twelve hours.

At the end of such a treatment, the patient is naturally more or less exhausted and this exhaustion is increased, if the initial time interval before a fever of 103.5° F. is reached, is unduly prolonged. There is also another difference between external and penetrating heat which has heretofore not been described. Though the body is a mass of colloids constantly irrigated by the blood stream and though the sympathetic nervous system attempts to keep all parts of the body at a constant temperature by the dilatation and contraction of the blood vessels, this constant temperature level is not to be viewed as a fixed unchangeable quantity. The surface of the skin functions at a much lower temperature than the interior. Normally at a rectal temperature of 99° F. the skin temperature registers about 95° F. During fever, the skin always remains cooler than the internal organs.

External Heat

Whenever fever is produced by external heat, the temperature of the skin rises above that of the internal organs and this difference is only equalized after the height of the temperature has been reached and the patient is about to cool off. Whenever penetrating heat is used, the temperature of the skin also has a tendency to rise because the capillaries expand in their attempt to cool the body. This rise, is, however, never greater than that of the interior. Later on when the patient is about to cool off, the original relationship, a difference of from 4 to 5° F. between exterior and interior temperatures, is quickly resumed. It seems hardly necessary to add that a biological tissue will function better under approximately normal conditions than under abnormal ones. It is true that all this makes little difference to robust patients, but many who might be benefited by hyperthermia are marasmic and have chronic ailments which make them poor risks for this form of treatment. Such individuals should not be treated by external heat. To this category belong severe asthmatics, advanced cases of organic nervous diseases, such as multiple sclerosis, and patients suffering from serious organic heart disease. These patients may, however, be treated with diathermy or radiothermy, provided certain safeguards are used. These safeguards, accurate temperature measuring devices, will be described later on.

The graph (Fig. 2) was made from temperature measurements of the same patient on three successive treatment days, about three actual days apart. It can be seen at a glance that the temperature rise at the time of the blanket treatment, plotted as a continuous line, is comparatively slow, and that a therapeutic fever of 103.5° F. is not reached until 2¼ hours have elapsed. After this, it takes another 1¾ hours to reach the finally desired height of about 105.8° F. This amounts to a rise of 6.6° F. in four hours. This curve further shows that the axillary temperature is at first 0.6° F. below the rectal temperature, later rises above it, but finally after the heat of the blanket has been turned off, falls back to its original relative position. The temperature curve obtained during the diathermy treatment is the most abrupt, hence the most efficient. It is plotted as a dotted line. A difference of axillary and rectal readings amounting to 0.2° F. is maintained during the entire time that the patient's temperature rises. A rise of 8.1° F. was achieved in two hours. The curve plotted during a radiothermic treatment, the broken line, falls midway between the diathermic and blanket curve in efficiency. A rise of 7.4° F. is recorded in 3¾ hours. These curves are all quite representative. Similar ones are constantly observed. The patient weighed about one hundred and fifty pounds; heavier patients show a slower heating incidence, lighter patients are heated up more rapidly. We therefore must come to the conclusion that all other factors being equal, the diathermic procedure is the most efficient, next the radiotherm, and finally the electric blanket is the least efficient. All three methods require the careful supervision of a physician.

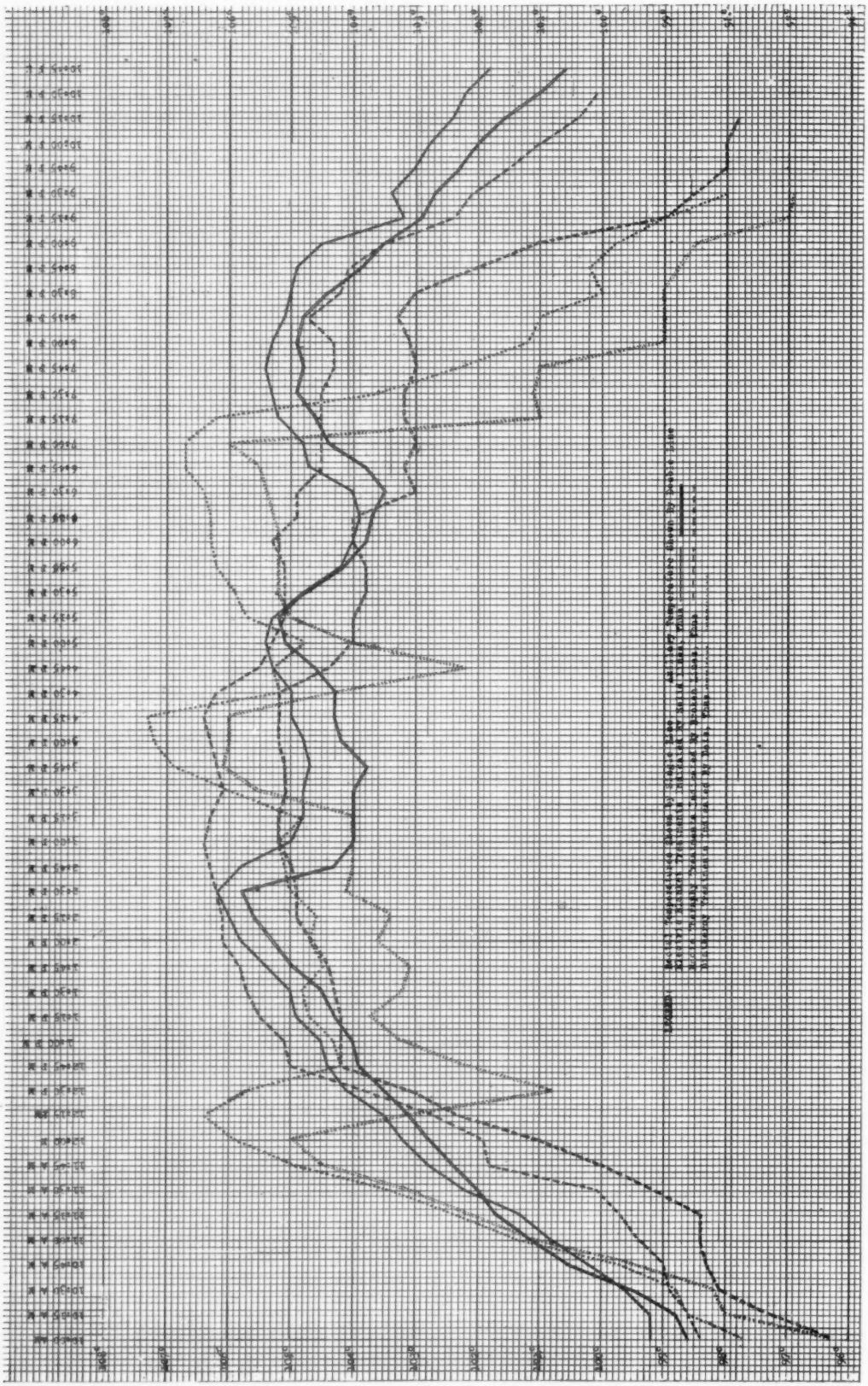

Fig. 2.
RECTAL TEMPERATURES
Rectal Temperatures Shown by Single Line. Axillary Temperature Shown by Double Line.
Electric Blanket Treatment Indicated by Solid Lines, Thus ————————
Radio Therapy Treatments Indicated by Broken Lines, Thus — — — — —
Diathermy Treatments Indicated by Dots, Thus . . . . . : : : : :

Fig. 3. Radiotherm treatment. Patient enveloped in zipper bag.

Technic

The technic of *diathermic* hyperpyrexia described by us elsewhere[9] must be carefully followed. If this is done and fenestrated, so-called Neymann electrodes are used, burns should not result. Burns are unnecessary and are due to carelessness and faulty technic. During the last nine months we have observed one burn the size of a half-dollar. This was due to inattention on the part of the technician. The electrodes were not smooth and one of the prongs was pressed into the flesh of the patient.

The *radiothermic* technic has lately been modified by us. Formerly the patient was placed inside of a coffin-like box while hot air blowers effected a constant movement of the surrounding preheated air. This was supposed to keep the patient fairly free from perspiration and thus prevent burns. It does neither. After the patient is removed from the box, his temperature falls rapidly unless he is put into a preheated bed and covered with an electric blanket. Hot water bottles placed around the patient, as recommended by Hinsie and Carpenter,[21] prolonged hyperthemia after the fever has been produced by means of the radiotherm. We therefore place the patient in a treatment bag as described by Feinberg, Osborne and Steinberg.[22] After the desired temperature has been reached, the patient is lifted out of the radiotherm, put to bed still enveloped by the practically air-tight bag. In this way he is not cooled off and a sustained fever is easily achieved. If a radiotherm is to be used at all, we recommend this technic (Fig. 3). There are many practical objections to the use of the radiotherm. Burns occur no matter what method is employed. These burns are not dangerous because they are usually superficial, but they may be quite extensive. Thus far, the experimental radiotherms are not built ruggedly enough to withstand long continued use. The oscillating tubes burn out, as well as the resistance coils and switches, even the canvas hammock and the wooden frame on which

Diathermy Treatments Indicated by Dots, Thus .....

Fig. 4. Blanket treatment. Rheostat and registering thermometer at foot of bed. This thermometer records the blanket temperature.

it is suspended occasionally catch fire. Because of the original cost and maintenance charges this machine is at present restricted to the field of research. The only advantage which seems apparent to us is that its high frequencies of ten to fourteen million cycles a second are less destructive to the fatty subcutaneous tissues. Very stout individuals are best treated by the radiotherm. The extravasation of subcutaneous fat so often observed in the obese after diathermic treatment, is never seen after radiothermic treatment. Burns, however, are much more frequent. These disadvantages may possibly be overcome in the future. The French have recently attempted to construct a more serviceable machine. At least, Poittevin[23] claims that his model is superior to the American prototype. On the other hand, American engineers who have studied the description of this French radiotherm, deny his claim.

We have already mentioned the outstanding defects of the original type of *blanket*. In the technic of this type of hyperthermia, we assume that a properly insulated blanket is to be employed, that this blanket is connected with a rheostat, and that a registering or indicating thermometer or thermocouple is used for measuring the temperature of the blanket surface. The idea that one simply envelopes a sick man with an electric blanket and waits for fever to ensue is contrary to common sense and good medical judgment. Blankets easily attain a surface temperature of 175° F., hardly a comforting thought when we pause to consider that water baths of 56° C. (133° F.) are in general use for the purpose of inactivating serum, and that this temperature kills bacterial cultures after a short time. Such degrees of heat are entirely unnecessary, and do not produce a much quicker temperature rise within the body than decidedly lower heat levels. We have made it a rule that the temperature between the patient's body and the blanket measured directly under his buttocks shall not exceed 116° F. By means of the registering or indicating pyrometer and the rheostat, the heat is under perfect control. In order to further safeguard the patient, he is separated from both the lower and upper halves of the blanket by two layers of absorbent fabric, and one layer of pure gum rubber sheeting. The outermost fabric is provided with a zipper, which prevents the disarrangement of these layers and excludes at

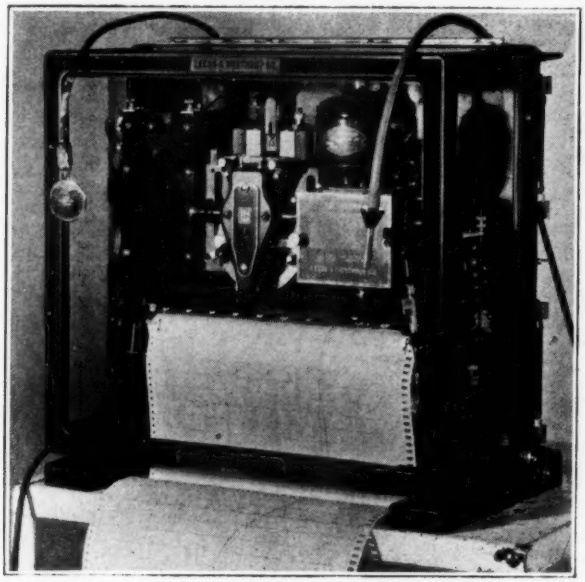

Fig. 5. Pyrometer for recording both axillary and rectal temperature. The axillary temperature is recorded by means of a resistance unit enclosed in the flat circular disk.

least part of the air currents. Fig. 4 illustrates the position of the patient in bed, the arrangement of the coverings, the rheostat and registering thermocouple.

We have already mentioned the value of automatic temperature registering or indicating devices, so-called *pyrometers*. These instruments are not only valuable for research purposes and as labor saving devices, but are of the utmost practical value. Two types have been developed, one an indicating, the other an indicating and registering instrument. Figs. 5 and 6 illustrate both types. The first, an indicating and registering instrument which writes a graph of both the axillary and rectal temperature, is especially valuable for ascertaining the incidence of the rise of the temperature curve. One can see exactly at a glance how steep this rise is and was during the entire period of treatment. Each time interval can be compared with the preceding periods. In this way the dosage of current can be regulated to exactly the required needs and one can prognosticate the time at which the current should be turned off, in order to reach the desired fever. Knowledge of the patient's hyperpyrexic state and tendency is available from moment to moment. The curve either rises or falls. It flattens out to a straight line whenever heat equilibrium has been reached.

The indicating pyrometer requires closer attention on the part of the personnel and does not supply automatic or written records. Because it is much simpler in construction without many movable parts, it is less apt to get out of order and can be handled and moved with less care. During radiotherm treatment, while the electromagnetic waves are passing through the patient's body, pyrometers cannot be used. They are also sometimes slightly affected by the diathermic currents. Hardly enough can be said in praise of these instruments. Repeatedly lives of patients have been saved by them and we attribute a good part of our exceedingly low mortality to their use. Thus far we have treated approximately two hundred patients and have given about four thousand treatments. Two deaths have resulted. We will discuss mortality statistics later.

Minor Technical Aids

Before abandoning the subject of technic, we wish to call attention to several minor points which concern the comfort and welfare of the patient. If we turn back to Fig. 4, it can be seen that the patient's feet are encased in bootees. These are made of two layers of cotton cloth stuffed with about an inch of kapoc or cotton. This is for the purpose of avoiding pressure sores of the toes and heels. Prior[24] described these ul-

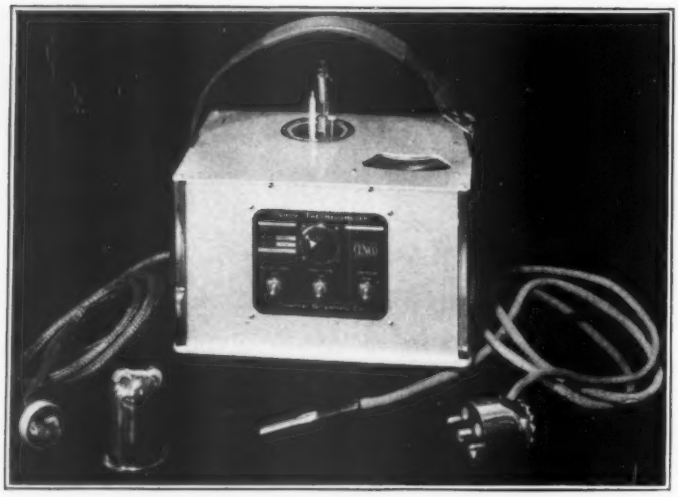

Fig. 6. Indicating pyrometer, so-called thermelometer.

cers and attributes them, as do we, to excessive sweating and remaining in one position for many hours. An air cushion should be placed under the sacrum of thin patients for the same purpose. Morphine gr. ¼, with or without hyoscine gr. 1/100, can be given restless patients after they have reached the maximum temperature. Luminal and paraldehyde may be used for the same purpose in certain cases. The patient should be given and in fact urged to take liberal quantities of cold water at all times. This does not appreciably decrease the temperature. When it is desirable or it becomes necessary to reduce the temperature, the following cooling procedures are to be used. First remove the patients arms from the pack, next uncover him partially, then uncover him completely and finally in case of an emergency, blow cold air over his body with an electric fan and douche him with ice water. Ice water enemas as recommended by Bishop, Horton and Warren[19] are not in themselves drastic enough to deal with an emergency. They may be used as adjuncts but vitiate all rectal readings because of their local cooling effect. The method is not without danger. Treatments in organic nervous diseases are usually given bi-weekly, two treatments are being given for asthma, one treament a week is given for arthritis.

It is not practicable to summarize the results of treatment in all diseases for which hyperthermia has been used. We will content ourselves with enumerating them in those conditions where this therapy is of definitely known and recognized value.

General Paresis

Foremost are certain organic conditions of the central nervous system, especially general paresis. Three years have now elapsed since the first group of paretics was discharged. Not a single case has relapsed. Thus we, the originators of this therapy, can now proudly state that in all probability these remissions are permanent. The following table gives a survey of all cases reported in the literature and brings our own work down to date:

CLINICAL RESULTS IN THE HYPERTHERMIC TREATMENT OF DEMENTIA PARALYTICA

Authors	No. of Cases	Complete Remissions	Improved	Died
Neymann & Osborne[2]	25	16	2	0
Cortesi[25]	8	3	3	0
Neymann & Koenig[7]	50	12	13	0
Perkins[26]	26	13	10	2
Wilgus & Lurie[20]	97	10	43	6
Hinsie & Blalock[27]	68	13	24	2
Prior[24]	16	9	3	0
Halphen, Auclair, Crozon[28]	15	4	4	0
Bamford[29]	13	1	0	0
Bishop, Horton & Warren[19]	18	13	0	1
Neymann, further cases to date	20	11	2	1
	356	105	104	12
Percentages	100%	30%	29%	3%

In studying this table two facts immediately become prominent, the low death rate and the large percentage of complete remissions and improved cases. There is, however, a great variation in percentage among

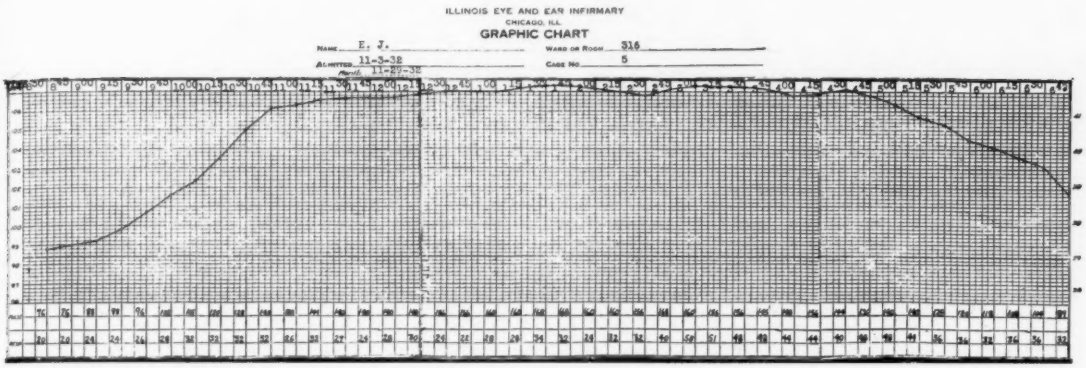

Fig. 7. Typical temperature curve during a treatment for general paresis with luetic optic atrophy. Temperature above 103.5° F. 8 hours, above 106.7° for 5¼ hours. Maximum temperature 107.4° F.

the different authors and even among the same authors. The results of Neymann and Osborne are much better than those of Neymann and Koenig. This is explained by the fact that in our first series we gave long intensive treatments and continued these until some patients had had forty-nine hyperthermic sessions while in the second series we contented ourselves with twelve less intensive periods of hyperpyrexia. The patients of Neymann and Osborne, Cortesi, Perkins, Prior, Halphen, Auclair and Crozon, Bishop, Horton and Warren and our final group were intensively treated, all the rest were treated conservatively. Bamford is the only author who reported poor results. The series of Hinsie and Blalock is especially interesting. These authors duplicated the temperature curve of malarial fever and gave approximately ten treatments to each patient. They ran a control series giving malaria with approximately ten paroxysms to an equal number of patients and achieved analogous results. We believe that they have brought the final proof that like temperatures produce like curative results. In this respect, a certain parallelism can be seen between this series and that of Neymann and Koenig, who made similar comparative studies.

There is a definite relation between the height and length of the fever and the number of treatments necessary to produce remissions. According to our experience, temperatures below 103.5° F. are therapeutically of little value in general paresis. Temperatures of 41° C. (105.8° F.) and above are of great value, especially if such temperatures are maintained for a number of hours. Temperatures above 42° C. (107.6° F.) are distinctly dangerous and are usually followed by heat prostration. Temperatures of 41.5° C. (106.7° F.) can be maintained for hours if the patient is most carefully supervised. Fig. 7 illustrates the very intensive treatment given to a patient with leutic optic atrophy and beginning general paresis.

Tabes

Besides general paresis, we have treated uncomplicated tabes and tabes complicated with optic atrophy with success. Crises have yielded to this therapy with astonishing promptness. Halphen and his school have made similar observations in France. This phase of the subject must, however, be reserved for a later publication.

Multiple Sclerosis

This disease of unknown or disputed origin has been the subject of our research for over a year. We have treated eighteen cases with complete or partial remissions in fourteen of them. We believe that we have partially solved the problem of an amelioration of this otherwise hopeless, progressive disease. While we do not feel in a position to make a definite report at this time, we intend to do this in the near future.

Hyperpyrexia has been employed by Halphen[28] and his school in the treatment of other organic brain diseases, hemiplegia, poliomyelitis, lethargic encephalitis, etc. Our own experience has been exceedingly limited and we must refer the reader to the original publications of this very active French group, to whom we wish to pay our utmost tribute and respect. These investigators, though they entered the field years after we had begun the work, have certainly supplied the world with reports on a wealth

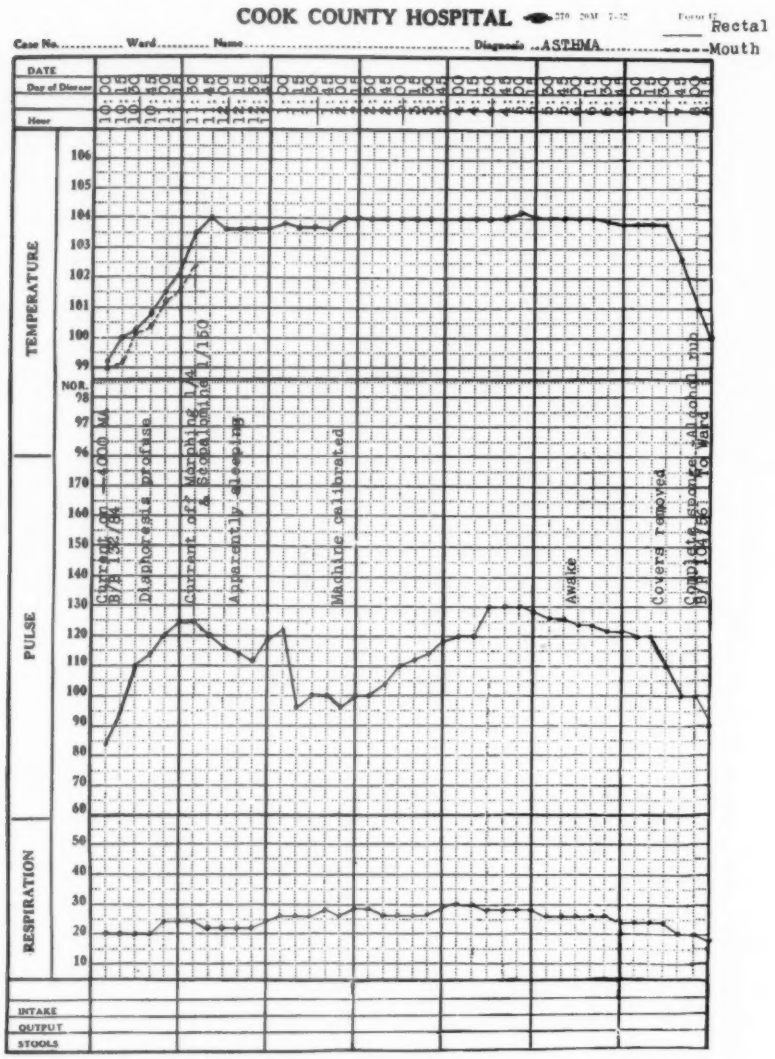

Fig. 8. Typical treatment for asthma.

of clinical material, which overshadows our own best efforts. Let us now leave the diseases of the central nervous system, and study two other disease groups, in which we believe hyperthermia to be a very important and valuable therapy.

Intractable Asthma

In the last two decades, the conception of allergy has resulted in great progress in the management of bronchial asthma. We know now that hypersensitiveness to such substances as foods, pollens, hairs, feathers, and others, is responsible for the etiology of the majority of the cases of asthma. In such instances, the treatment is based on the etiologic factors and aims at elimination of, or desensitization to, these materials. By this procedure many asthmatics have been relieved of their symptoms. In addition to these specific measures, a successful outcome is obtained now and again with such therapy as bacterial vaccines, x-ray treatment, eradication of sinus infection, change of climate, and other measures. We wish to emphasize that whatever we shall say about fever therapy, the above methods are still the procedures of choice in the majority of instances of asthma.

With all the modern advances in our knowledge of asthma, there still remain many individuals whom our usual methods afford no relief. These, as a rule, belong to the non-allergic type of asthma. Their paroxysms occur daily, or several times a day,

and they may not be free from asthma at any time. In these cases allergy has been investigated and been found either not demonstrable or its results unproductive. Other methods have been tried without avail. Many of these also have complications, such as emphysema or bronchiectasis. This group constitutes what is known as the class of intractable asthma. It was this class of individuals whom we had in mind when we were seeking for a remedy which might give them some degree of comfort, and it was this type that we selected for treatment by the method to be described.

It has been observed repeatedly that chronic asthmatics improve or become entirely free from their asthma during the course of an acute infection, and usually for some time afterward. This has been noted frequently during such diseases as pneumonia, pleurisy, scarlet fever, measles, chicken pox, abscess, typhoid fever, and other infections. This clinical observation led us nearly two years ago to conceive the idea that fever artificially produced might accomplish similar results. It is admitted that there are other factors than fever in operation in an acute infection, and yet no one is prepared to say whether the fever or something else is responsible for the effect described. It seemed logical at least to hope that fever without infection may produce a similar result.

Several methods of producing fever were considered and rejected. Foreign proteins intravenously were deemed dangerous, sulphur intramuscularly too painful, malaria too drastic, and hot air, electric blankets, and hot baths lacking in sufficient control. We finally adopted the method of inducing fever by electropyrexia using the diathermic current.[30], [31], [32]

Management of the Patient. The first essential is the thorough examination of the patient prior to any fever treatment. This examination has several objectives. The first objective is to decide whether other methods of therapy may be beneficial. This, of course, requires either prolonged efficient observation or a history of such observation. The second objective is to decide whether fever treatment can possibly accomplish anything. If, for example, a great deal of the patient's difficulties are due to a complicating emphysema, bronchiectasis, or heart failure, then such treatment, or any other, cannot be expected to produce results. Finally, one must evaluate the patient's general condition to decide whether such treatment is safe. This should include a urinanalysis, blood count, electrocardiogram, and any other tests indicated to satisfy oneself on this score.

The patient must be hospitalized at least for twenty-four hours during the treatment, and preferably including the two or three days between the treatments. The most satisfactory results have been secured with a temperature curve slightly above 103.5° F. for eight hours. The temperature chart in Fig. 8 gives an excellent illustration of an ideal treatment curve. Only a light breakfast, consisting of fruit juice, coffee and toast, should be given prior to treatment. During the treatment, fluids in the form of water or fruit juices are to be given freely. The free use of liquids does not interfere with the elevation of the temperature while the deprivation of them may produce marked discomfort and undesirable symptoms. After the treatment, in the evening, the patient may have a full meal.

Asthma attacks may occur during the course of the treatment. These should be treated with adrenalin if the patient is known to respond to that drug. If discomfort becomes severe or if the patient becomes very restless, the use of sedatives is advisable. We have found an hypodermic injection of gr. ¼ of morphine sulphate to be suitable in the majority of instances. This may have to be repeated in some cases. Some individuals either do not respond to morphine or cannot tolerate it. In those, we have employed either scopolamine or amytal.

Reactions — Physiological and Chemical. A number of physiological reactions occur which one may expect as part of the treatment. Tachycardia is quite proportional to the temperature rise. The respiratory rate is usually only slightly increased. Perspiration is usually profuse. Restlessness is the ordinary physiological response.

In addition to the above, many patients have some nausea, and one or two instances of vomiting have occurred. Herpes labialis occurs quite frequently, as a rule on the following day. Muscle cramps have occurred in three instances, possibly due to

loss of chlorides by the profuse perspiration. It should go without saying that in case of alarming symptoms such as marked distress, weak or irregular pulse, marked cyanosis, or any other serious signs, the treatment should be discontinued.

Some of the laboratory changes are worthy of note. The erythrocytes and leukocytes tend to show an increase during the fever, although this is not always the case. The neutrophilic polymorphonuclear leukocytes increase while the eosinophiles decrease. Blood pressure readings indicate only a slight rise in the systolic and diastolic pressures. There is a loss of two to five pounds of body weight during the treatment, apparently chiefly a water loss. This loss is usually regained in one or two days. In the cases benefited by this treatment the vital capacity determinations showed an increase after treatment.

The urea and non-protein nitrogen of the blood showed an increase during the fever. There was very little change in the acid-base balance as indicated by determinations of the carbon dioxide combining power of the venous blood. Alkalinization of some of the patients prior to treatment had no effect on the therapeutic outcome. The above facts argue against the possibility that the beneficial effect of fever on asthma is due to the production of an acidosis.

Further work was done on the atopic reactions of the blood in an attempt to gain an insight into the mechanism of the action of fever upon asthma. These results were negative. The complete report of these results and a discussion of the possible mechanism involved may be found elsewhere.[22]

Results. In all, fifty-two patients with chronic asthma were treated by this method. The analysis of the results is based on forty-four cases. The remaining eight are omitted because of insufficient data, lack of failure to report, etc. Of the forty-four cases analyzed, twenty-two or fifty per cent, received a complete remission. This period of remission or entire freedom from asthma was of a duration varying from one week to nine and one-half months. Fourteen of the forty-four or thirty per cent had definite improvement in their symptoms but no actual cessation of the asthma. The remainder, or twenty per cent, may be considered as absolute failures.

In the majority of instances, the results followed the administration of two treatments, with an interval of two or three days between them. This is arbitrarily designated as a "course." In some, this course was repeated later when the effects of the previous treatment had subsided.

Subsequent to our first preliminary report, Leopold and Stewart[33] reported seven cases of chronic asthma treated by fever induced by diathermy. While their results were as a whole unsatisfactory, they felt that it "offers a new therapeutic measure, which is worthy of more extensive clinical trial in certain types of chronic bronchial asthma." An analysis of their case protocols makes it evident that the duration and the degree of the fever would explain their failures. At the same time Miller and Piness[34] recorded their observations of seven cases treated in a similar way. An analysis of their data would lead one to believe that in two of these cases the results were worth while. These workers depended on a single treatment. Possibly their results would have been better if they had given another treatment two or three days after the first one. This has been our usual technic. Auclair,[28] of Paris, has lately confirmed our findings. He has treated eight cases of asthma and states that remissions promptly occurred in all of them.

Conclusions. This treatment for chronic asthma was designed for use only in those asthmatics who do not respond to such usual and accepted treatment as allergic methods and non-specific methods of the ordinary type. While it is true that many of the eighty per cent who were improved obtained relief for only a comparatively short period even that is worth while in some instances. The relief obtained by several over a number of months lends additional encouragement to the use of the method in suitable cases.

Finally, an emphatic warning must be sounded that such treatment of an asthmatic should only be undertaken by a physician who is competent to judge the vagaries of asthma.

Arthritis

The results achieved by means of sustained electropyrexia in the treatment of general paresis and asthma suggested

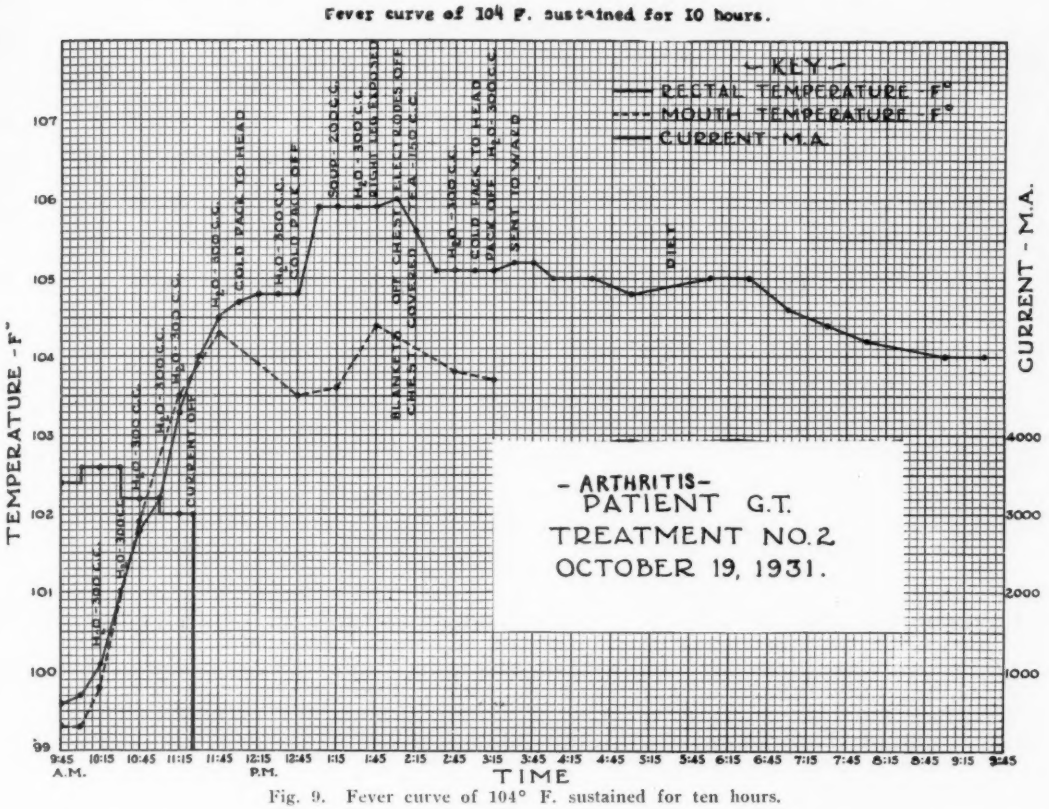

Fig. 9. Fever curve of 104° F. sustained for ten hours.

that this type of therapy might have a rational basis in the management of arthritis. The safety of the method, the ease with which any type of fever curve could be produced, and the complete control of the operation at all times convinced us that a new therapeutic approach had been found. The observations which had been made with non-specific protein[35] could thus be analyzed.

A wide variety of these proteins are in general use, such as, milk, aolan, peptone, mirion, sulphur, omnadin, typhoid vaccine and mixed vaccines. It occurred to us that in the group where fever was produced, the results were decidedly better than in other groups. At first, short temperature curves were employed[36] simulating the nonspecific type of reaction, in other words, curves ascending in two or three hours to 103° F. and descending to normal in the same period. The results of this régime were unsatisfactory, therefore higher curves sustained for a longer time were produced. Fig. 9 illustrates the type of curve which is now generally employed. It will be noted that the rectal temperature reached 104.6° F. in three hours and remained above 104° F. for ten continuous hours.

Technic. In the application of the diathermic method of hyperpyrexia for the treatment of arthritis, the technic used is essentially the same as that previously described; the only exception being that the plateau of the fever curve is lower but wider than that used in treating general paresis. Obviously these treatments must be given in a hospital under the constant supervision of a nurse who is familiar with all the details of the technic as well as the reactions which occur. A physician must be on call at all times. Preferably the patient enters the hospital on the night before and is placed on a light diet. Following breakfast at 8 A. M., the treatment is started and requires at least twelve hours for its completion; that is, until the patient's temperature returns to normal. During the following night, a sedative is usually required and the next morning the patient is permitted to go home.

Selection of Cases. Probably our greatest error in the experimental stage of our work arose from an improper selection of cases.

Having become more familiar with the method and its limitations, our cases are now chosen entirely from the infectious group. Infectious arthritis is used synonymously with rheumatoid arthritis of the British and the proliferative type described by Nicholls & Richardson.[37] This group includes the younger arthritics whose cardio-vascular systems are able to withstand this rather strenuous treatment. However, individuals with compensated hearts and valvular lesions, mitral stenosis or insufficiency, or both, withstand the treatment very well. A few cases of acute simple endocarditis with polyarticular symptoms improved decidedly with shorter curves of a lower plateau than those ordinarily used. The hypertrophic group has a high incidence of cardio-renal disease[38] and should, therefore, be excluded from treatment with this method. It belongs with the degenerative diseases and should properly be called an arthrosis, to distinguish it from the inflammatory conditions of the joints, or the arthritides. In addition to the degenerative changes in the joints, such patients have other manifestations of degenerative disease, myocarditis, arteriosclerosis and nephritis. With these facts in mind, we were, nevertheless, persuaded to try this new method in four cases of hypertrophic arthritis. In each instance, the attempt nearly ended in disaster; one patient developed a fibrillation; another showed signs of myocardial failure; still another developed an acute delirium, and the fourth showed signs of vasomotor collapse. No deaths occurred because we abruptly terminated the treatments and applied restorative measures.

In order to obviate such experiences, all patients selected are first thoroughly examined in the general medical clinic and are then re-examined according to the routine plan which for many years has been in use in the arthritis clinic.[39] With this routine it is possible not only to rule out the vague syndromes simulating arthritis, but one is in a better position to judge the patient's ability to withstand electropyrexia. The case report to follow illustrates this point:

Case History

G. H., white, female, forty-seven years old, was admitted to the arthritis clinic, May 22nd, 1931. Her complaints on admission were as follows: Pain and swelling in the second carpal articulations of the left index and mid fingers; limitation of motion and pain in the right knee and elbow; pain in right lumbar region, referred to the right lower quadrant of the abdomen; sore throat present all the time, with occasional acute exacerbations.

This trouble began acutely two and one-half years ago with pain and swelling in the carpo-metacarpal articulation of the left index finger. This condition persisted for a few days and began to subside. Since that time, at irregular intervals, the following joints have been involved in the order named: right hand, left knee, both elbows, both wrists, and ankles. With each new attack, the joints suffered more injury until the condition as described on admission now exists.

Physical examination: P. 84, T. 98⁶° F., R. 22, Wt. 180, Ht. 66½ inches, B. P. 148-88. Obese white female, chronically infected tonsils, marked pyorrhea with gingivitis and recession of gums; limitation of motion in the flexion of the right knee and elbow. Otherwise the general physical examination was essentially negative. Laboratory data were as follows: B. M. R. plus 2, Kahn and Wassermann negative, blood chemistry, B. U. N. 11, N. P. N. 23, uric acid 2.9, sugar 91.5, R. B. C. 4,910,000, W. B. C. 10,150, Lymph. 33, Mono. 1, Poly. 66, urinalysis, epithelial cells and mucus shreds. Examination by the ear department showed acute tubal catarrh of the right ear. X-rays, teeth negative, no evidence of apical infection; sharpening of the bifid spine of the tibia and some proliferative changes on the articular angle of the patella of the right knee, probably due to infectious arthritis, the joint space normal; E. K. G. negative; kidney function normal.

Care of the teeth was immediately begun by the dental department, tonsillectomy was performed. Other treatments consisted of autogenous vaccine from the tonsils, electric baker, massage, body-mechanic exercises, reducing diet and thyroid. Improvement under this régime was slow and unsatisfactory so that diathermic treatments were recommended on October 12th, 1931. The course of eight treatments was completed December 19th, 1931, no other treatment having been given in the interval. The results of this fever therapy were quite striking. There was marked relief from pain and stiffness in fingers, wrists and knees; the motion in right knee and elbow was markedly improved. Fig. 9 is one of the temperature curves of this patient and Fig. 10 gives a survey of the same patient's condition during the entire treatment.

Condition and Reactions of Patients During Treatment

The pulse rate and pulse pressure furnish the best guide to the patient's condition during treatment. Both of these should be taken every fifteen minutes. The intense vasodilatation that occurs is shown by an increase of the pulse pressure of from 30 to 40 mm. of mercury. The systolic pressure remains stationary or slightly increased, with a marked drop, as indicated, in the diastolic pressure. At the height of the fever,

G.T. ARTHRITIS - Treatment #2. October 19, 1931

Time	Galvan. Deflect	C.J. Temp.F°	Rect. T.C.	Mouth Temp. F°	Currant M.A.	Pulse	Resp.	Remarks
AM								
9:45	9.0R	76.75	99.6	99.3	3400	90	16	
10:00	8.5R		99.7	99.3	3600	94	16	H_2O 300 c.c.
15	7.0R		100.1	99.8	"			Sweat slightly Acid
30	3.0R		101.0		"	110	16	H_2O 300 c.c.
45	0	76.8	101.8	101.9	3200			H_2O 250 c.c.
11:00	2.0L		102.2		"	122	16	H_2O 300 c.c. Sweat Neut
15	6.5L		103.3	103.5	3000			
30	9.0L		104.0		Off 11:25	124	24	H_2O 100 c.c.
45	11.5L		104.5	104.3				H_2O 300 c.c.
PM								
12:00	12.0L	76.9	104.7			120	20	Cold pack to head
15	12.5L		104.8	103.9				" " "
30	12.5L		104.8			118	20	" " " H_2O 300 c.c.
45			104.8	103.5				Cold pack to head off
1:00	13.5L	77.0	105.9			114	26	Gal. Recalibrated
15	13.5L		105.9	103.6				Soup 200 c.c.
30	13.5L		105.9			120	18	H_2O 300 c.c.
45	13.5L		105.9	104.4				R. Lower Leg & Hand Exposed
2:00	14.0L		106.0			120	26	Electrodes Off, Blankets back.
15	12.5L		105.6					Covered again
30	10.5L		105.1			128	22	H_2O 300 c.c.
45	10.5L		105.1	103.8				Cold pack to head
3:00	10.5L		105.1			128	20	H_2O 300 cc Pack off
15	10.5L	77.2	105.1	103.7				
30	11.0L		105.2			124	20	Returned to Ward
45	11.0L		105.2					
4:00			105.0					
30			105.0					
5:00			104.8					Diet
30								
6:00			105.0					Total Fluids - 2950 c.c.
30			105.0					Intake
7:00			104.6					
30			104.4					
8:00			104.2					
9:00			104.0					
30			104.0					
10:00			103.7					
11:00			101.6					Part of Blankets off
11:30			101.4					Sponge bath. Alcohol Rub
12:00			100.4					

Fig. 10. Table of temperature chart Fig. 9.

anxiety and restlessness are prominent features. This restlessness is probably a physiological method of improving venous return.[40] In the average case, morphine sulphate, gr. ¼ hypodermically, relieves the unrest. In the event of a very sharp rise in the systolic pressure which may indicate beginning circulatory failure, treatment should be discontinued at once. The fluid loss due to the profuse perspiration is partially replaced by the liberal supply of fluids as shown in Fig. 10. The perspiration which, at first, is acid soon becomes neutral and remains so during the entire curve. In certain patients there is a peculiar distribution of the sweating, the upper part of the body may be bathed in perspiration while the lower part may remain dry. The same patient during a subsequent treatment may show generalized sweating, or, the reverse of the previous observation may be seen. The fever curve of patients suffering from arthritis is strikingly characteristic. The mouth temperature crosses and recrosses the rectal temperature. The normal relationship of the two is quickly reestablished if the current is turned off as is shown in Fig. 9. Joint pains may become extremely severe during the initial temperature rise, later they disappear. Intense local reactions at the site of previous typhoid or other vaccine injection have been observed in a few cases. A severe chill, lasting one-half hour, may occur in this same group. For this reason we now stop all other treatment for at least one week prior to the date of hospital entry. The later reactions which occur two or three days after treatment are, herpes labialis, weakness, loss of weight, intense joint pains, which soon subside, and loss of appetite, which returns and remains distinctly better than before.

Laboratory Data. Ruth E. Jung[41] from the laboratory of Dr. Alexander Day made the following studies on patients F. D., and N. P.: Opsonic index, complement content,

ARTHRITIS

4-22-31 Case 12	Opsonic Index	Complement Content Serum in 1:5 dilution 0.01	0.03	0.05	0.10	0.15	0.20	0.30	0.40	Agglutinins	Blood Count R.B.C.	W.B.C.	Polys	Lymp	Eos.	Trans	Mono.	Baso
First Treatment Before Rx	1.0	½	1	1	1	1	1	1	1			5800	54	44	1	1	0	0
Height Rx	1.2	-	+	++	++++	++++	++++	++++	++++	+1:40		9700	79	18	2	1	0	0
After Rx	0.9	-	-	+	+++	+++	+++	++++	++++	+1:40		9300	78	18	1	2	1	0
5-8-31 Fourth Rx Before	0.8	-	+	+	++	+++	+++	++++	++++	+1:80	3,530,000	5200	63	35	1	0	0	1
Height	0.8	-	+	+	++	+++	+++	++++	++++	+1:20	4,530,000	14000	72	26	0	0	1	1
After	0.6	-	+	+	++	+++	+++	++++	++++	+1:40	4,830,000	7400	60	38	2	0	0	0
5-27-31 Eight Rx Before	1.0	-	-	-	+	++	++	+++	+++	Lysis 1:40	3,960,000	5400	56	42	1	1	0	0
Height	0.9	-	-	-	+	++	++	+++	+++	sl.Lys 1:60	4,675,000	17100	78	20	0	2	0	0
After	0.7	-	-	-	+	++	+++	+++	++++	sl.Lys 1:60	5,130,000	5700	62	37	1	0	0	0
Unheated sera-probably accounts for lysis in later specimens and its absence in earlier specimens #2° bath about 35° cc instead of 37° cc																		
Case 13 4-27-31 Fourth Rx Before	1.0	-	+	+	++	+++	++++	++++	++++	+1:80	4,270,000	8700	73	25	0	1	0	1
Height	1.6	-	½	+	++	+++	++++	++++	++++	+1:80	5,890,000	12800	71	28	0	1	0	0
After	1.0	-	½	+	++	+++	++++	++++	++++	+1:40	6,360,000	9300	60	36	2	2	0	0
5-7-31 Sixth Rx Before	0.9	-	+	+	++	+++	+++	++++	++++	+1:80	4,280,000	8900	55	37	5	1	2	0
Height	0.9	-	½	+	++	+++	+++	++++	++++	+1:40	4,890,000	12200	71	28	0	0	1	0
After	1.0	-	+	+	++	+++	+++	++++	++++	+1:80	4,970,000	7400	65	33	1	0	1	0
5-15-31 Eight Rx Before	0.9	-	+	+	+++	+++	+++	++++	++++	31 Lysis 1:40	5,130,000	9400	60	38	2	0	0	0
Height	1.7	-	½	+	+++	+++	+++	++++	++++	S. L. 1:80		12000	65	32	1	2	0	0
After	1.1	-	½	+	+++	++++	++++	++++	++++	+1:80 ±1:60	5,725,000	9200	47	48	3	2	0	0

Fig. 11. Serology and blood counts in arthritis.

agglutinins, r. b. c., w. b. c. and differential counts. The blood was drawn before each treatment, at the height of the curve, and, the next morning after treatment. Blood counts were made at identical times. Fig. 11 shows in detail the results obtained. The leucocytes show a marked rise at the height of the curve, the erythrocytes are only slightly increased. There is a relative increase in the polymorphonuclear leucocytes and a tendency for the eosinophiles to disappear at the height of the fever. We have no explanation as yet for the absence of eosinophiles. It will be noted that there is only a slight change in the opsonic index and, in the light of our present knowledge of complement, one may say that there is no variation from normal. The blood lactic acid determined under similar conditions was also within the range of normal. Sedimentation rates following the treatment correspond with clinical improvement.[42] These blood chemistry studies correspond with those described previously.[43]

Clinical Results

Fig. 12 gives a resumé of the total number of cases treated. In group (A), the first series of six cases have been observed over a period of twenty months. Four of this group have remained free from pain and stiffness of the joints up to the present time without any further treatment. Patient N. P., returned for treatment last month complaining of pain in both knees, but the original severe pain, swelling and stiffness in both ankles, which was so intense that she could not walk, did not return. The other patient, now residing in Florida, developed a bacterial dysentery with a consequent return of her previous symptoms.

In the group (B), seven cases, each of whom received one complete course of eight weekly treatments, have all been observed for periods less than one year. Five of this group have been markedly improved; three of these have returned to work. Two, however, showed no decided improvement with the exception of some relief from pain.

It is impossible to evaluate the results in the group of five patients who received nineteen treatments, and who, for various reasons, did not have a complete course. However, J. P., who was treated for two and a half years for a proliferative arthritis of the right hip, improved remarkably after three treatments with a decided increase in mo-

(A)

Patient	Age Sex	Duration	Type	Joints Involved	Previous Treatment	Hyperthermia	Results
D.K.	34 f	3½ yrs.	Chronic infectious	Fingers, wrists, knees, cervical spine. Partial ankylosis of left knee (fixed in partial flexion). Motion extension 150°, flexion 90°.	Removal of tonsils and infected teeth. Non-specific vaccines. Physiotherapy (radiant heat, infra red, muscle training, home physiotherapy). Orthopedic (cast to left knee). Clinic treatment 1 year.	Began April 16. Ended May 15. 8 weekly treatments.	Improved. Is able to walk in erect position. Motion in fingers and wrists markedly improved. Now able to do own housework for first time in 3 yrs.
N.P.	34 f	4½ yrs.	Chronic infectious	Fingers, wrists, shoulders, knees; walks with difficulty because of pain in both ankles.	Treatment of chonic suppurative sinusitis. ---- chronic purulent otitis media and chronic endocervicitis. Vaccines --- colon diet physiotherapy management of constipation. Clinic treatment 1 year.	Began April 22. Ended May 22. 8 weekly treatments.	Markedly improved. Relief from pain and stiffness in all joints. Is now able to walk without pain.
E.C.	34 f	3 yrs.	Chronic infectious	Polyarticular. Flexion deformities of fingers of both hands and elbows. Partial ankylosis of knees, walks with cane.	Tonsillectomy. Vaccines and non-specific therapy, arsenicals, iodides. Clinic treatment 6 months.	Began May 21. Ended June 25. 8 weekly treatments.	Improved. Relief from pain. Loss of 10 lbs. wt. Able to walk without cane.
D.F.	18 f	18 mos.	Chronic infectious	Wrists, elbows, knees, shoulders and fusiform swelling of fingers.	Began at once with diathermy.	Began July 23. Ended Sept. 21. 8 treatments.	No improvement. Patient did not co-operate. Temperature curve not sustained.
D.P.	45 m	14 mos.	Subacute infectious	Polyarticular especially the proximal interphalangeal joints 3rd and 4th fingers of left hand. Unable to work 6 months.	Tonsillectomy. Treatment of prostatitis, autogenous vaccines, physiotherapy. Clinic treatment 3 months.	Began May 20. Ended July 8. 8 treatments.	Markedly improved. All pain and stiffness entirely relieved after 4th treatment. Iritis improved after third treatment.
E.P.	31 f	3 yrs.	Chronic infectious	Right wrists, ankles, knees. Difficulty in walking. Cannot straighten arms and legs.	Tonsillectomy. Vaccines, physiotherapy, body mechanic exercises. Treated 1 month in clinic.	Began June 5. Ended Aug. 17. 8 treatments.	Improved. Entirely relieved of pain. Can do her own housework.

(B)

L.M.	51 m	9 mos.	Chronic infectious G.C.	Spine, tempero-mandibular articulation. Inability to open mouth completely, cannot straighten back.	Treatment of posterior urethritis and otitis media. Tonsillectomy - care of teeth - hot baths - vaccines, etc. Clinic 5 months. Slight improvement.	8 treatments	Complained of weakness, loss of 12# wt., but all pains relieved. Can straighten back without discomfort.
C.C.	35 f	5½ yrs.	Chronic infectious	Wrists, elbows, knees, ankles. Partial ankylosis of right elbow and fingers, ankylosis left knee and wrist. Rheumatoid arthritis, nodes on both forearms.	Treatment in many institutions and clinics - no improvement. Clinic - 9 months.	8 treatments.	Marked relief from pain and stiffness in joints. Increased motion in fingers, wrists and knees.
G.S.	46 m	3 yrs.	Chronic infectious	Cervical spine, left elbow, right shoulder, both feet and wrists. Partial ankylosis right elbow.	Tonsillectomy. Vaccines, radiant heat, massage, baths. - no improvement. Clinic treatment 2 years.	8 treatments	Decreased pain and stiffness. Limitation of motion right shoulder and left elbow - unimproved.
J.G.	29 m	5 yrs.	Subacute infectious	Polyarticular especially hip joints and cervical spine.	Treatment outside clinic 4 years. Tonsillectomy, care of teeth, physiotherapy. In clinic - vaccines, radiant heat, massage, etc. No improvement.	8 treatments	Polyarticular pains. Markedly relieved.
P.J.	41 m	6 mos.	G.C. Arthritis	Ankles and right hip. Swelling, pain, stiffness of both ankles. Limps because of pain.	Treatment in G.U. Dept., posterior instillations, etc. Arthritis Clinic, vaccines, radiant heat, etc. Slightly improved.	8 treatments	Markedly improved after 2nd treatment. Swelling and pain disappeared. Can walk without limping.
L.J.	40 f	5 yrs.	Chronic infectious	Fingers, wrists, knees, elbows, ankles. Partial ankylosis of wrists and elbows and fingers. Difficulty in walking stairs due to stiffness.	Treated in many clinics. Our clinic for 2 years, with indifferent result.	8 treatments	Can ascend and descend stairs with ease. Fingers and wrist motion increased. Decidedly less pain and stiffness.
G.T.	47 f	2½ yrs.	Chronic infectious	Limitation of motion and pain right knee and elbow, pain and swelling of fingers of left hand, lumbar pain.	Care of teeth. Tonsillectomy, autogenous vaccine, baker, massage, body mechanic exercises, reducing diet, thyroid.	8 treatments	Marked improvement. Motion in rt. knee and elbow markedly improved. Relief from pain decided.

Thirteen patients were each given one course of eight treatments.
Five patients not included in above table were given a total of 19 treatments.
Total number of treatments given to 18 patients, one hundred and twenty-three.

Fig. 12. Survey of results in eighteen cases of arthritis.

tion of that joint and a gain of twelve pounds in weight. This case is mentioned because of the striking result after only three treatments. Our recent reexamination of this patient shows that he has had no return of the severe pain and limp which originally existed.

In summarizing the results of one hundred and twenty-three diathermic treatments administered to eighteen resistant cases of arthritis, who had been treated by the well established methods for periods ranging from six months to five and one-half years, it may be said in all fairness that this method offers a new hope for these patients. Of the group who received a full course of treatments, sixty-nine per cent were markedly improved, fifteen and one-half per cent were improved and fifteen and one-half per cent were unimproved; in other words, eighty-four and one-half per cent of the total group were improved. Of course, the number of cases treated is too small to be conclusive, however, if one judges from the standpoint of the duration of these remissions, the evidence of an amelioration of the disease seems decidedly more convincing. Further, it is worthy of note that in our tabulation no notice is taken of the fact that the maximum benefit often begins about three months after treatment is discontinued. Other authors have also reported favorable results in treating this disease with electropyrexia. Bishop, Horton and Warren[19] state that fifteen unselected cases were benefited. Auclair, Emery and Weil[28] are very enthusiastic proponents of this therapy in the treatment of arthritis, gout and rheumatism. They, however, cite only a small number of cases. In conclusion we wish to state that this method is not offered as a cure for arthritis, nor are the facts presented intended to convey the impression that it will replace all other types of established therapy, but rather is it presented as a new method which now offers much more hope for intractable cases.

Rationale of Therapy. In attempting to rationalize the beneficial results of the diathermic method in infectious arthritis, one must review the pathologic physiologic studies that have been done on the circulation of these patients. Wright and Pemberton[44] have reported tests which show a lowered surface temperature, a decreased blood flow, and a lessened ability on the part of tissues to adjust themselves to changing temperatures. Direct capillary studies[45] on these cases by a modified Lombard technic reveal a narrowing and a closure of the capillaries, with an itermittent and irregular filling and sluggish responses to such vasodilators as erythyrol-tetranitrate, histomine and heat.[46] Leriche[47] attributes this inefficient circulation to dysfunction of the sympathetic vascular control. On the same basis, it may be that the intense vasodilation produced by diathermic hyperpyrexia is responsible for the excellent clinical results reported. In the final analysis, however, a satisfactory explanation must be sought by the investigations of the future.

Conclusions. Diathermic hyperpyrexia in the treatment of chronic infectious arthritis, has been established as a valuable method in cases that do not respond to ordinary therapeutic procedures; the results of this treatment are excellent, provided the fever is sustained for a sufficiently long period of time; there is no danger, if ordinary care is used. One hundred and twenty-three treatments have been given without a single death.

Summary

The various methods of hyperpyrexia have been discussed and a brief resumé of the technic of diathermic, radiothermic, and blanket electropyrexia has been given. Certain suggestions for the improvement both of the apparatus and of their application have been made. These suggestions are not to be considered as final attainments, but only as steps towards the ultimate goal of a safe and sane procedure.

Results in the treatment of general paresis, multiple sclerosis, asthma and arthritis are summarized. These results include the work of other authors and of our own group. Briefly stated, about sixty per cent of the cases of general paresis have been cured or improved, seventy-five per cent of the rather small series of patients suffering from multiple sclerosis have derived some benefit, fifty per cent of our asthmatic cases showed remissions lasting for shorter or longer periods and eighty-five per cent of the selected arthritic group were definitely benefited.

These clinical results seem to us distinctly orth while and to warrant wider applica-

tion of electropyrexia. We realize that with the exception of the general paretic group, the series is not large enough to permit us to reach final conclusions. The reports of other investigators on the treatment of syphilis of the central nervous system with electropyrexia combined with our material have definitely established the value of this therapy. Over three hundred and fifty cases have appeared in the literature. The combined death rate of all investigators is about three per cent, while that of malarial therapy varies between ten and thirty per cent.

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HIGH LIGHTS IN ELECTROSURGERY

HOWARD A. KELLY, M.D.

BALTIMORE

It seems to me that we can best impress the younger men entering the field of electrosurgery by tracing the new principle through its historical evolution and then stating clearly the claims of electrosurgery in those selected groups in which it is superior to the surgery by the cutting knife, the ligature, and the suture. It is my plan, therefore, in the following propositions to celebrate in several procedures the dethronement of the very insignia of the surgeon's art and to substitute a simpler, better, and more effectual way of doing certain things within the surgical realm.

At first sight, electrosurgery in a measure resembles the time-honored cautery, but such resemblance is after all only superficial, as will be seen; while in a remarkable way analagous, the new agent realizes all we formerly hoped for but signally failed to accomplish. Older surgeons in particular are apt to treat it lightly, prepossessed with the notion that it is but another species of cauterization.

The cautery goes back in our history some three thousand years or more in the form of heated irons used destructively to annihilate diseased tissues, to act as a counterirritant. In our literature it comes down to us from Hippocrates. Avicenna substituted cautery for knife. Well do I recall the joy in the early eighties of using my first Paquelin with its platinum point and blunt blade which, once started, held its heat as long as the bulb was squeezed; this we replaced later by the flat copper blade electrically heated. John Byrne of Brooklyn, introduced the galvanic current to heat a blunt knife blade on a cone in the vaginal extirpation of the cancerous cervix, and got better results than any of us with our much more risky abdominal operations. Later, Downes of Philadelphia, devised, and a few of us tried out, platinum clamps which we crushed down on the vessels, and then with an electric current cooked the tissue to a thin white ribbon — a method presumably safe, but we failed to see any great advantage and were afraid to give up ligatures. The Percy cautery, too, did some good work in the capable hands of its originator and had a vogue for a time but not, I think, a large one.

With this broad survey we arrive at the present day diathermy, endothermy, and electrosurgery, the latter of which differ from

previous exploitations of electricity in that the current passes through the body and is concentrated at the point of a needle or other small receiver, where an intense heat is developed within the tissues themselves, instead of being conveyed to them from without as in all cautery methods.

The first great step was taken in 1891 and 1893, when d'Arsonval made the physiological observation that while low frequency currents cause pain and muscular contractions, those above ten thousand alternations per second give rise to no discomfort but are accompanied by the generation of heat in the tissues, with a soothing effect.

At the same time (1893) P. Oudin constructed a coil without an iron core called an autotransformer (solenoid), one end of which he connected to a d'Arsonval apparatus, while from the other end of the coil he took off a uniterminal current, the intensity of which varies with the number of turns of the solenoid. Such an apparatus gave a much higher voltage with lower amperage than the biterminal d'Arsonval connection. This current was adaptable to fulguration and desiccation.

Rivière, de Keating Hart, and Pozzi put the Oudin current to a practical use to eradicate malignancy and called it fulguration; this was used successfully by Edwin Beer (1910) to destroy tumors of the bladder, and by Keyes (1910), and by me (1912). In attempting a larger use, fulguration was found to be too superficial.

It was Doyen of Paris, who, after much experimentation, modified the d'Arsonval bipolar current of high frequency and low tension and applied the term electrocoagulation to its effect in the tissues.

With these preliminaries we reach the marrow of the matter, when William L. Clark began his work in Philadelphia; acknowledging valuable aid from Finley R. Cook and Edward C. Titus of New York, Clark carried the matter so far as to deserve the title, progenitor of electrosurgery in America. According to his account published in 1910, he altered a fulguration apparatus and added a multiple spark gap to gain amperage, or current, at the expense of voltage, or potential, under perfect control; with this new instrument, which ever since its inception has been undergoing improvement, he began carving out new fields from the old realm of major surgery with the new agents, electrodesiccation and electrocoagulation. His work was at once put upon a scientific basis by his microscopic studies of the tissues (a distinction also to be credited to Doyen and later to Ward and others).

In 1904, Cohen of Berlin, experimenting to devise cutting currents, used a damped (spark gap) current machine made by de Forest. Four years later, Neil, Beer, and Sternberger, working with de Forest in New York, used his first radio tube cutting apparatus, later so satisfactorily amplified and established by George A. Wyeth, whose work occupies an important place in present day electrosurgery.

Many surgical operations now appeal to us through these novel methods in an entirely new sense, well-calculated at first sight to astonish and confound our predecessors, were we but able to call their spirits back to the operating table once more. One can well imagine how astounded they would be to see a needle, as it were, turned into a scalpel by the invisible current as well as used to shrivel instantly a minute tumor on the eye, or to witness the heavier currents destroy a large area of malignancy elsewhere, or, again, to follow the successful extirpation of the superior maxilla, pursuing the disease on into the depths and out into the oral cavity and that, too, with so little bleeding. And as for our brain surgery, it would surpass their fondest imaginations. Let me, then, with this prodrome, enumerate categorically and somewhat in detail, the numerous advantages offered by electrosurgery:

1. Local infiltration and gas anesthesias have a wide use, as has also avertin.

2. The tissues are not handled, manipulated, dragged, pulled, or pinched — acts tending to devitalization and to the distribution of malignancy or infection.

The operation from start to finish is a knife and fork affair, proceeding within the limits planned.

3. Bleeding is notably lessened, whether radio-tube or multiple spark-gap machine is used in incising, coagulating, or dissecting out the condemned area.

4. Ligatures are largely unnecessary, thus eliminating foreign bodies, which are at times dangerous in wound areas.

5. Larger bleeding vessels picked up with pointed forceps are coagulated by the forceps-conveyed current. In illustration, a complete

radical breast operation has been done without a ligature; this method calls for extended observations to demonstrate its safety.

6. Because of lessened shock due to diminished bleeding, and because of the facility afforded by the long instruments which convey and apply the current to remote points, the operations undertaken are often such as have been impossible for scalpel and ligature surgery. Notable fields for such beneficent activities are cancer, involving the superior maxillary or the fauces, or difficult brain tumors, or chest operations to liberate the adherent lungs.

7. The simplicity of electrosurgery will greatly increase the number of operations on the multitudinous skin affections.

8. In large lesions it is often well, as inaugurated by Clark, first to apply the coagulation current to circumscribe the area down through the skin or surrounding mucosa and, dissecting it up on all sides, roll it in on itself and remove it *in toto*.

9. The initial plan may be easily altered to exceed the limits prescribed in order to extend the area of extirpation in one or another direction, an awkward matter in scalpel surgery.

10. Many electrosurgical operations proceed with greater rapidity than those by the classical procedure, due to saving time in controlling bleeding vessels as well as to the greater ease of dissection and eradication with the cutting current. As a rule, the operation proceeds smoothly and rapidly from start to finish.

11. The coagulating current can be used to create a zone of sterilized tissue about 1 cm. in width, a comfort in the circumvallation of a larger carbuncle associated with a similar treatment of the central area or, in a smaller carbuncle, in the sterilization of the center alone. It is also invaluable in opening up a carbuncle for drainage.

12. The heavy current of increased amperage is of the utmost value in extirpating malignancy, where we secure a necrobiosis in the surrounding zone and sterilize the mass of disease which may then be left to become detached as a sterile slough in the convalescence. A word of caution: Don't forget the proximity of any large vessels and nerves.

13. Note that the current seals the circumjacent lymphatics.

14. The involvement of the nerve endings in the process of the coagulation often affords a painless convalescence.

15. A well-handled electrosurgical convalescence is short and agreeable. In the absence of shock and pain, one is often surprised the next morning to find the patient smiling and comfortable.

16. A vast amount of hospitalization is saved by the ambulatory nature of much of the work. This increases the effectiveness of the hospital by reserving its beds for more serious cases, a matter of especial import when we casually accept over thirty thousand deaths and some three hundred thousand or more accidents yearly as a natural and proper tribute to the use of automobiles and trucks.

17. The after-care while simple, is yet of the utmost importance. Mercurochrome 2 per cent in acetone and alcohol forms a delicate bacteriostatic protecting pellicle. On mucous surfaces gentian violet (acetone and alcohol) gets a faster hold and is more effectual.

18. Continued careful supervision of larger wound areas by the responsible surgeon is wise.

19. The resultant scar yields a far better cosmetic result and is more supple, a fact most noticeable in extensive operations near the eye, where ectropion is avoided.

20. Electrosurgery, particularly in extensive operations about the face, is a stimulus and an inspiration to the plastic surgeon. The sound circumjacent tissues form a fertile field for transplants.

There are often several elective objectives in an operation in seeking in every case the annihilation and thorough extirpation of malignancy; the thorough destruction of any scattered disease (it may be a gland under the skin or in the abdomen, on the pelvic floor, or in an angle between vessels) by needle punctures with a strong current, leaving the mass for absorption; the destruction of superficial disease, left to be discharged later, meanwhile kept well-protected and sterile; the annihilation of a cancerous metastatic nodule in the wall of the intestine, covered by drawing the adjacent peritoneum over the area. Papillary tufts scattered over the peritoneum can be destroyed more rapidly than it takes to tell about it.

Our new surgery calls for a variety of special instruments. To enumerate: A machine to furnish current with accurate voltage and amperage controls; a large indifferent pad to

convey current to the body; a cold needle, wire loop, small metal ball, plate, or narrow blunt knife to carry the concentrated current; an insulated metal aspirator carrying the coagulating current to keep the blood out of the field and seal the bleeding vessels (G. E. Ward); an active wire loop to scoop out the diseased area; sundry special instruments, as for example for tonsils, prostate work, brain tumors, hemorrhoids.

The mastery of electrosurgery is a matter of months of study and painstaking practice; after years of experience one will still be learning. A distinct danger is that of undertaking some of our work in too cavalier a fashion and dismissing the patient without the assurance of due observation and after-care. To avoid this, I urge surrounding our operations with all the pomp and circumstance in dress, cleaning up, use of gloves, care in anesthesia, and sequestration of the field of operation, which characterize all major surgery.

A new momentum has entered the surgical realm, one which although far from claiming an exclusive right to any of its broad fields, has, however, discovered a distinctive terrain where it does better work and is more efficient and should, therefore, receive a hearty welcome. Let us give thanks for this late and unexpected adjuvant.

THE TREATMENT OF MALIGNANT GROWTHS OF THE ORAL CAVITY *

WILLIAM L. CLARK, M.D.

PHILADELPHIA

Neoplasms of the oral cavity possess in general the same characteristics and manifest the same behavior as tumors arising elsewhere. The relative degree of their benign or malignant nature is influenced to a considerable extent, however, by the anatomical and functional properties of the structures involved. For a better interpretation of the nature of neoplasms in general, and those of the oral cavity in particular, one must take into account not only the clinical and histological data, but also the biological elements concerned in the development and growth of the tumor.

Our knowledge of neoplasms is meager at best; what little knowledge we have is frequently thrown into confusion because of our failure to visualize the problem as a whole, and to link the clinical and histological evidences with the biological factors. From the clinical aspect the line of demarcation between benign and malignant tumors appears well defined, and rests upon the basis of special characteristics common to both. Viewed histologically the line of demarcation, while still evident, becomes less distinct. To the histologist all neoplasms represent a functionless mass of proliferated cells. From the biological viewpoint all neoplasms are malignant in that they are parasites and live at the expense of the host. Thus the borderline between benign and malignant neoplasms becomes more distinct, or less distinct, or entirely obscured, according to the particular viewpoint of the observer.

Clinically, we look upon malignant disease as distinct and apart from all other diseases. Histologically, however, neoplasms possess certain things in common, resembling acute and chronic inflammatory tumors in that they represent an aggregation of proliferated cells, but differing in the type of cell composing the tumor, the polymorphonuclear in acute inflammatory tumors, the lymphocyte or fibroblast in the subacute or chronic inflammatory tumors. Biologically interpreted, neoplasms are found to have a property possessed by other diseases, which is based upon an in-

* Read at the Eleventh Annual Session of the American Congress of Physical Therapy, New York, September 8, 1932.

Fig. 1. Squamous epithelioma — Grade 4 — involving the lower lip and alveolus.

Fig. 1A. Result of one desiccation operation and radium to neck.

herent attribute common to all living cells, namely, reaction to irritation. The manifestation of this reaction is cell proliferation and multiplication. Whether the proliferated element be a polymorphonuclear, fibroblastic, endothelial or neoplastic cell is, in a great measure, determined by the type and intensity of the irritant.

Whatever be the cause of neoplasms, it appears to be activated by a common factor — chronic irritation. In no other part of the body can one trace such close relationship between persistent irritation and development of malignant growths as in the oral cavity. The mouth and its structural contents because of their peculiar anatomy and function, are frequently subject to minor trauma. A jagged tooth, ill-fitting denture, loose bridge, irritating material, such as tobacco, etc., act as irritants, and are apt to initiate a chronic inflammatory process. The inflammatory reaction persists because healing is prevented by several agencies present in this particular location, such as frequent passage of food, the general mobility of tongue and buccal surfaces, and the presence of bacteria whose activities are enhanced by the already devitalized area and the moisture and temperature of the mouth. A vicious circle is thus established.

To exemplify, a chronic inflammation of the tongue is induced by any of the above mentioned irritants, resulting in a chronic glossitis. The inflammation persists, not only because of the particular irritant giving rise to it, but because of the location of the lesion in this particular structural and functional environment. A chronic glossitis is established, with the formation of fissures in the inflamed area which refuse to heal. The surface epithelium in the affected zone eventually responds to this persistent irritation in the form of proliferation and multiplication of its cells, leading to an overgrowth of the surface epithelium, manifested clinically as raised white patches (leukoplakia). With the continuation of this vicious circle the hyperplastic epithelium sooner or later assumes greater activities and the simple overgrowth of the surface epithelium advances. Thus leukoplakia may be looked upon as the precursor of lingual carcinoma.

Again, carious teeth frequently lead to multiplication of the paradental epithelium. The hyperplastic cells, like those of the surface epithelium of the tongue, may eventually assume neoplastic activities, giving rise to an adamantinoma of the maxillae.

As stated above the behavior of benign and malignant tumors is influenced by the anatomy and function of the structures involved. This applies particularly to the mouth. Thus, a papilloma of the tongue, buccal surface, etc., is more likely to undergo malignant changes, than papilloma elsewhere. Carcinoma of the tongue or floor of mouth is, as a rule, very destructive, and metastasis is more rapid and

Fig. 2. Squamous cell epithelioma of floor of mouth and alveolus — Grade 4.

Fig. 2A. Result of one desiccation operation and radium to lymph nodes. No recurrence in eight years.

earlier than in other locations. The tongue is supplied by a double lymphatic system, one branch draining the submucosa, and the other the muscularis; these practically envelop the whole organ from base to tip and, after pursuing an irregular course, send their tributaries to the submental, submaxillary, and the deep and superficial cervical lymph nodes. The lower deep cervical lymph nodes are located upon the jugular vein, the upper deep cervical near the common carotid, just above the point of bifurcation. The rich lymphatic network therefore offers many avenues for the travel of the various cancer cells to the neighboring lymph nodes. The location of the lymph nodes and their relation to vital structures influence in a great measure the clinical course of malignant disease of the mouth.

While squamous cell carcinoma is the growth most frequently encountered, one not infrequently meets with other types in the oral cavity, such as sarcoma, adamantinoma, epulis, papilloma, hemangioma and lymphangioma. Epulis, adamantinoma and papilloma, though classed with benign tumors, may

Fig. 3. Squamous epithelioma. Grade 2 — of cheek and angle of lips, extending through into the mouth.

Fig. 3A. Result of one electrocoagulation operation under ether anesthesia; radium treatment to lymphatic drainage areas. No recurrence in six years. A plastic operation to close opening into mouth could be successfully performed.

Fig. 4. Squamous cell carcinoma of parotid gland, ear, lower jaw, with infiltration into neck.

Fig. 4A. Result of combined coagulation, radium treatment, and resection of lower jaw. Patient is living without recurrence after ten years.

assume active growth and pursue a malignant course.

The grading of tumors according to the method of Broders, gives some indication as to prognosis, and has an influence on the choice of treatment. Since the actual etiologic factor is still unknown, no specific having yet been discovered, we must use such methods as have proved to be of value in combating this disease. They include surgery, x-rays, radium and electrothermic methods (desiccation, cold high frequency knife and coagulation). While surgery plays an important rôle, its usefulness has in many cases been enhanced by the employment of x-rays or radium as pre-operative and post-operative adjuncts. In certain instances x-rays and radium, either singly or in conjunction, have entirely replaced operative surgery. Like surgery with the scalpel, desiccation and coagulation remove the tumor growth, but, unlike surgery, they do not act as a mere physical agent, removing the growth en masse, but destroy the neoplastic cells in situ to some depth below the actual tissue involved.

In the removal of the neoplasm, while the chief object is the destruction of the malignant cells, a secondary important factor is the maintenance and preservation of the adjoining healthy tissue, and that is influenced in a large measure, if not altogether, by the associated degeneration and fibrosis. The observation that the resulting scar in the use of electrodesiccation and coagulation is soft, and not as extensive as that resulting from the use of other methods, may not only be confirmed clinically, but also explained histologically.

The electrothermic methods are governed by certain fundamental principles. They are dependent for their results upon the resistance of the tissue to the current, which manifests itself in the formation of heat. The high frequency current used in desiccation is of a relatively low amperage, producing only a moderate degree of heat, but of sufficient intensity to cause complete evaporation of the fluid content of the cell. The coagulation current is, on the other hand, of comparatively high amperage and low voltage and induces such intense heat that the cells are not only dehydrated, but their protoplasm is coagulated as well.

The microscopic picture of neoplastic tissues submitted to desiccation presents typical characteristics. While the cells still retain their outline, they appear shrunken and elongated and present a dried up appearance, not unlike that seen in mummification necrosis. Evidences of such degenerative changes as hydropic or fatty degeneration are not discernible. The blood vessels in the immediate and adjacent vicinity of the field of operation are thrombosed. In tissues subjected to coagulation, there is complete loss of cell outline. The neoplastic cell elements seemed to have fused into a structureless, homogeneous mass, giving it a hyalinized appearance. The blood vessels and lymph channels are thrombosed. The secondary and associated changes in all such lesions are regeneration and fibrosis. Whether the fibrous connective

tissue shall be abundant and dense or less abundant and soft, is influenced by the amount and nature of the accompanying degenerative and necrotic materials, which in turn are determined by the particular type of irritant. Thus, following desiccation the fibrosis is slight and the resulting scar is soft and pliable. Following coagulation the fibrosis will be more or less abundant, depending upon the intensity of the heat generated and the consequent degree of frame destruction. The size of the subsequent slough or sequestrum, where bone is involved, is therefore largely under the control of the operator.

Many years of experience have demonstrated to me that malignant disease of the oral cavity, while always a most serious affection, is not necessarily hopeless, since many brilliant results are obtained by the judicious employment of the methods mentioned; of which the electrothermic method for treatment of the local lesions holds first place.

Operative surgery may frequently be employed to advantage for the ligation of blood vessels, thus preventing possible secondary hemorrhage, or to expose a growth in the antrum for example, so that the electrothermic method may be employed to better advantage. The use of radium and the x-rays are used in my practice principally to control metastasis to the cervical lymph nodes, and their value for this purpose has been definitely established.

1930 Chestnut Street.

D'ARSONVAL'S SERVICE TO SURGERY

GUSTAVUS M. BLECH, M.D.

CHICAGO

With governments, scientific bodies and individual scientists paying tribute to Professor Arsène d'Arsonval, a review of the influence of the work of the celebrated French savant on the science and art of operative medicine is a rather difficult task.

It should be understood at the outset that an exact evaluation of d'Arsonval's contribution to modern surgery must remain a good deal of a problem, for reasons which will be given in this article.

D'Arsonval's contribution to present-day surgery centers in the high frequency current, from the standpoint of an addition to operative technics. In other words d'Arsonval's researches and discoveries have placed in the hands of surgeons a method of operative therapy for which the generic term *electrosurgery* is undoubtedly the most appropriate.

To the initiated this bare statement implies a tribute of deep gratitude to d'Arsonval, as an electrophysiologist, whose discoveries have benefited suffering humanity. Unfortunately to the uninitiated electrosurgery is still a sealed book.

One wonders that in this era of scientific progress there is a veritable chasm between two classes of surgeons. One — the minority — hails the use of the high frequency current as "the newer surgery," while the other — the majority — rejects electrosurgery as an "innovation" of no consequence. Such a sharp contrast between practitioners of one and the same discipline cannot be dismissed with a mere shrug.

My opinion, based on a limited investigation, coincides with that tersely expressed by Dr. Disraeli Kobak, namely, that "people are usually down on things they are least up on." While this contains a large kernel of truth, it must not be forgotten that the "anti's" assert that if electrosurgery had produced striking therapeutic results, it would have long since become common property. Naturally the "pros" resent such a claim as due to prejudice or downright indifference to a valuable addition to the surgical armamentarium.

With such a wide divergence of opinions, it is believed that the best way in which surgeons can pay their homage to the jubilarian in the special issue of the ARCHIVES in honor of Professor d'Arsonval, is to present an impartial evaluation of the present stage of electrosurgery.

For this purpose it may not be amiss to establish a historic basis. It is a far cry from Ambroise Paré, the "father of French surgery" of the sixteenth century, to Arsène d'Arsonval, the exponent of electrophysiology of the twentieth century, and yet one finds a connecting link between the two periods and men. In the sixteenth century, surgery—such as it was — was practiced by uncultured barbers or itinerant charlatans, so that there was some justification for the "pure physicians" to arrogate to themselves the right of supervision over the activities of the barber-surgeons, even though official medicine then was in the throes of fantastic "systems" mixed with a good measure of superstition. Ambroise Paré, cultured, academically trained, and skillful surgeon, did not share the contempt of the physicians for the barber-surgeons or feldshers (military barber-surgeons) but made every effort to raise surgery to a higher level. This effort was emulated by others almost throughout Europe, so that eventually the universities had to incorporate surgery in their curricula.

Today the pendulum seems to have swung to the other extreme. Many surgeons look upon their particular discipline as the "queen of medical crafts" and are prone to accord internal medicine only a subordinate place in the sun. When one considers that both internal medicine and operative medicine have the same anatomico-physiologic fundament, that their methods of diagnosis are virtually identical, then one can only conclude that surgeons consider their calling to be superior, solely because their therapy involves manual dexterity, the results of which are concrete, whereas the results of other methods of therapy can at best be accepted only as a *post hoc, ergo propter hoc*. Freely translated this means that patients might have gotten well without or in spite of medical care.

Such a smug viewpoint leads to a conviction that anything not emanating from the guild is dubious. But history teaches that others than surgeons have rendered valuable services to surgery though they were not at once appreciated for want of striking effects. This is not the time nor place to substantiate what has been said, but a few examples will illustrate the fact that the usefulness of any discovery can be established only after the lapse of a good deal of time. Who, for example, would have guessed that the discovery of the ophthalmoscope would prove of immense value to brain surgery? Who could have foreseen the tremendous rôle the discovery of the x-rays would play in general and special surgery? Who surmised that the study of an accidental gastric fistula would be the stimulus to the development of gastro-intestinal surgery? And who even dreamed that the manufacture of incandescent lamps would eventually revolutionize the diagnostics and treatment of affections of the bladder, sigmoid, stomach, bronchi, esophagus, etc.?

D'Arsonval's work has escaped the fate of certain great discoveries in that it has not experienced bitter antagonism, but, if it really has any value — and we shall show that it has — then indifference is just as bad, if not worse, than decided opposition.

Before outlining the clinical value of electrosurgery let me first remind the reader that, not unlike all other disciplines of medicine, surgery has still a number of serious problems to solve. What availeth it that the technic of operative therapeusis has been developed to perfection when even the most skillfully performed operation contains elements of risk which can neither be foreseen nor prevented? Thrombosis, embolism, infection, paralysis of viscera, acute dilatation of the heart and the like, hang like a Damocles sword over the head of every surgeon. Even the danger of implanting malignant cells into the lymph vessels or structures adjacent to the operative field still is the bugbear of surgery of the malignancies.

What wonder then that conscientious surgeons have earnestly sought means which will reduce operative therapy to the minimum. Both internal medicine and physical therapy have been resorted to, so that one may say that instead of carrying on useless skirmishes at ill defined frontiers, friendly cooperation between the inhabitants of opposing camps has served the common good.

And right here it is opportune to point out that if electrosurgery has done no more than add a factor of safety to modern surgery it has a *raison d'être*.

Electrosurgery being a generic term, attention is invited to the restriction in this review to electrocoagulation and electrodissection, for which latter the term "electrotomy" merits general adoption. The reason for this restriction is purely personal, for I have had no experience with the other available methods by di-

verse modalities, as, indeed, this review is based solely on my own clinical experience.

Electrosurgery has beyond doubt its greatest usefulness in the field of malignancies, internal or inaccessible as well as external or accessible neoplasms. We know that in spite of x-rays and radium early and radical surgery offers the best chance of cure. Allusion has already been made to the danger of surgically producing metastases. Classic surgery, that is operation with scalpel and scissors, has endeavored to overcome this drawback by dissecting out the neoplasms from within apparently healthy tissues. Although surgery has triumphed in very many instances, favorable outcomes have neither been as numerous nor as complete as was desirable. As a consequence attempts have been made to replace the scalpel by the actual cautery. There can be no doubt that the destruction of tissues by intense heat has greatly reduced the incidence of postoperative metastases. Though this method represents an advance in surgery, it could not become very popular for purely technical reasons. Cauteries, irrespective whether they were heated by an electric current (galvanocautery) or by an inflammable gas (Paquelin) or by fire (actual cautery) become so intensely hot that even towels placed around the handles of the appliances do not help in reducing the great discomfort to the hand of the operator, so that lengthy operations become veritable tortures for the surgeons. In addition even the best appliances are too bulky for careful dissection, and the effect of actually burning the tissues not only obscures the operative field but escapes good control. Accordingly the cautery had to be restricted to operations in which the organs or tissues to be destroyed are away from blood-vessels, nerves or organs which cannot be sacrificed.

With the introduction of the high frequency current for the surgical treatment of malignancies we secured a method which has all the advantages afforded by any and all forms of heated cauteries without their disadvantages.

It is not my intention to enter into technical details beyond what is needed for our purpose, for that would mean "carrying owls to Athens," but it is of interest to note that I have learned from a number of surgeons that they have regarded electrosurgical methods as being scarcely different from galvanocauterization, which of course was "old stuff" to them. This experience has convinced me that many surgeons have rejected the employment of electrosurgery without investigation or on mere hearsay evidence.

Suppose we not only agree with the opponents of electrosurgery for the sake of argument or, better still, reasoning, that electrosurgery is a modified form of cauterization, but are even willing to discount the fact that one can operate with an electrotome or even a coagulating electrode for any length of time without experiencing any other sensation than one would have by operating with a scalpel, we still hold the trump card that electrosurgery contains elements of safety which cannot be overemphasized.

Apart from the assurance that in electrotomy we have a means of destroying every cell, malignant as well as benign, during the act of dissection, so that implantation of malignant cells into the lymph stream or into adjacent structures is virtually impossible, every experienced operator has noted with utmost satisfaction either the total absence of shock or so great a diminution of shock as to be a negligible factor. The investigator seeking an explanation for this favorable circumstance must for the present content himself with the theory that the nature of the high frequency current prevents an electrolytic effect on the animal cells. Whether this theory is correct or not matters little, for, barring extreme cases in which the anesthetic alone is a hazard, I have yet to see a case of real shock even after such extensive operations as ablation of the mammary gland (radical operation) or gastrectomy.

Another striking effect which, too, may be explainable by the theory just given, is the absence of postoperative pain. While this does not come under the heading of "safety," modern surgery cannot ignore any factor that tends to render operative therapy less disagreeable in its after effects. I confess that I have been more than amazed when after ablation of the external ear or even after more extensive operations the patients were resting in comfort, so that there is hardly ever any need of administering a sedative or narcotic.

The slight coagulating effect of the high frequency current used for electrodissection (electrotomy) checks all oozing from capillary blood-vessels and a mere adjustment of a dial of the apparatus suffices to yield a current

which can obliterate the lumen of a cut blood-vessel of small size, reducing sponging of the wound and ligatures to the minimum, advantages which favorably affect healing of wounds by first intention.

So far, then, as electrotomy is concerned, we have a convenient method of attacking malignancies, which enables the surgeon to accomplish his work with comparative ease and which is relatively safer than classic surgery, at least from the standpoint of metastasis, provided operation is undertaken at an early stage of the affection.

Whether or not electrotomy is capable of preventing thrombosis or embolism must remain an unanswered question until cumulative statistics will be available. To point out that this or that operator has had no such sad experience to date is meaningless, because the material is too small numerically for definite conclusion. But this much may be pointed out to substantiate the claim of the relative safety of electrotomy: that the cutting current necessarily destroys vegetable as well as animal cells, so that pathogenic germs are killed by it. If the theory that thrombosis and embolism are due to infection is correct, then it must be conceded that any technic which contains sterilizing properties will prevent infection. This is supported by clinical experience. While aseptic precautions and post-operative care have been carried out as rigidly as for example in laparotomies by the usual method, no local or general infection has been observed in electrotomy, whereas in an equally large series of operations by the classic method a few cases of wound infection have been almost the rule.

When we consider the styptic properties of the high frequency current in surgery, the thought suggests itself that electrotomy certainly should be advantageous in operations involving vascular organs. Many surgeons have, naturally, employed this method in surgery of the liver, gall-bladder, thyroid gland, prostate, etc., and even in resections of hollow viscera, and have been more than pleased with the ease of the procedures and the improved operative results. While I have had no personal experience with the high frequency current in brain surgery, one cannot but regard with serious consideration the work of one of our greatest neurosurgeons — Cushing — which leaves no room for doubt as regards the following theses:

1. Electrotomy facilitates dissection of all kinds of tissues, thereby greatly reducing the operative time element.

2. Electrotomy makes possible continuous dissection through a comparatively dry field of operation, saving time, preventing loss of blood, and reducing surgical trauma.

3. Electrotomy reduces traumatic shock incident to operative procedures, thereby rendering it the method of choice in operations involving the central and peripheral nervous systems.

With what has been said in mind, it is no wonder that no less a surgeon than Howard Kelly has coined the word: "the newer surgery," which has been adopted by many adherents of electrosurgery.

But where there is much sunshine there also is shadow. An impartial review would be incomplete or even guilty of omission, were the disadvantages of electrosurgery to be ignored. Besides, there are arguments brought up by opponents which may as well be answered here.

First and most important is the apparatus. Where classic surgery is performed by a few scalpels and scissors, the apparatus needed to provide currents to coagulate and to cut tissues is large, complicated, and costly.

This is no argument against electrosurgery. The cost may and doubtless does affect a large number of occasional operators, but should not affect hospitals. No one has raised a protest against the expensive and complicated apparatus used for the administration of general anesthesia, which, in my humble opinion, are entirely unnecessary, since certain simple methods requiring appliances costing next to nothing are equally effective and equally safe. Why, then, should hospital managers not expend a like amount of money to add to the element of safety of operations? The bulkiness of the high frequency current apparatus is also not greater than that of the various anesthesia outfits. Complications of the apparatus are not at all formidable from the standpoint of manipulation, being a trifle more than is needed to adjust an ordinary household radio. Even if the apparatus were complicated, it is simply the duty of every progressive surgeon to learn how to use his tools. That will not prove half as difficult as many seem to imagine.

Next in importance comes the question of risk incident to the use of any electric current

giving off sparks near inflammable gases, such as are produced by certain anesthetics. The answer to this objection is that with ordinary care and certain precautions, which are now routine, there is no possibility of an explosion of the gases. Incidentally this "scare" has had a good effect in that a number of surgeons have been stimulated to perform many electrotomies under methods of analgesia and anesthesia other than by inhalation.

Finally an objection to electrosurgery that has been heard, was to the effect that as in electrotomy the division of the tissues is accomplished through the creation of heat within the tissues — in contradistinction to the heat being carried from without by galvano- or thermocautery — there is a risk in operating near large blood-vessels and nerves. Thus it is admitted that I, in common with a number of other operators, have been actually afraid to remove visible glands in the axilla in operations for carcinoma of the mammary gland, so that I extirpated the breast by electrotomy, but cleared the axilla with the scalpel. This objection no longer holds good. With a simple change of technics, involving a proper adjustment of the current and the use of an electrode in the shape of a small ring or loop, one can plane off a gland not unlike a carpenter planes off a board to the desired depth, provided the loop or ring is held flat, say like a curette. By this procedure I have removed malignancies of the canthus without in the least injuring the eye or adjacent structures.

Limitation of space prevents me from entering into further details. The use of the high frequency current in the now popular form of diathermy for surgical infections or rather for their after effects suggests itself. Many affections of the joints have been treated conservatively or mechanically with the aid of diathermy. Fibrous anchylosis can now be managed with less discomfort than has been possible with the use of external heat. This is no reflection on the methods advocated by August Bier, which I have introduced to American surgery. Nor can I conclude without pointing out that the present conservative methods of operating for prostatic hypertrophy, the intravesical extirpation of tumors by the high frequency current applied through a cystoscope, and the like, have already brought about a trend towards conservative urologic surgery. And what greater ideal can there be in surgery than compliance with the law: *Non nocere!*

What the future of electrosurgery will be like, can only be conjectured. Just as the use of the high frequency current in medicine has not come out of the brain of d'Arsonval like Athena jumping out of the head of Zeus clad in full armor, so the use of the high frequency current in surgery will have to be developed still farther to enable conservative surgeons to accomplish their work as close to the ideal as is at all humanly possible. From what has been attained so far, one is certainly justified in foreseeing a great future for electrosurgery. That it will never replace classic surgery goes without saying; that it will, however, greatly enhance our operative results in selected types of operations is no longer a matter of doubt. While d'Arsonval has fully earned the gratitude of physicians, scientists, and even industrialists, he has indirectly at least rendered surgery an incalculable service, adding additional glory to his life devoted to the advancement of science. *Palmam qui meruit ferat!*

FURTHER CONSIDERATIONS OF DIATHERMY IN MALIGNANCY *

GUSTAV KOLISCHER, M.D.

CHICAGO

The numerous experiences that have confronted the surgeon in connection with diathermy of malignant tumors call for an analysis of the causes of its successes and failures. Two problems are most obvious: explanation of the favorable results and consideration of the possibilities of reducing the number of failures.

The technical details of successful electrosurgery in malignancy are most aptly dealt by other of our essayists, consequently I shall confine myself to the discussion of some general principles.

The conviction is definitely gaining ground that in any surgical intervention for malignancy local and regionary destruction and general systemic reaction are of equal importance. The destructive facilities of electrosurgery are so obvious that some enthusiasts assert that there are no inoperable cases so far as surgical diathermy is concerned.

The systemic reaction is clinically evidenced by the rapid general symptomatic improvement that in most instances follows electrosurgery even if definite results may not be obtained.

Intense research work has demonstrated that around the region of electrocoagulation there develops an area of intense reaction accompanied by a copious immigration of defensive cells, thus establishing the concept of the perithermic zone. This phenomenon explains occasional complete therapeutic results in instances of only a partial destruction of the tumor.

Failures therefore must be ascribed to the lack of proper systemic reaction, which as a rule is described in a very inclusive but not sufficiently explanatory term as the poor individual resistance of the patient. In analyzing this general term one has to consider the patient's reaction toward infection and his local and general reaction against the tumor proper.

Infections in and around the malignant growth are most insidious factors apt to impair the results of any therapeutic effort. Experienced radiologists for instance, maintain that coexisting infection will materially reduce the efficacy of radium therapy.

In combating coexisting infections we have at our command local and constitutional methods. Drainage and local applications of chemical compounds have limited usefulness only. Electrocoagulation while having an immediate sterilizing effect will invariably lead to secondary infection during the period of separation of the scab.

The ideal goal would be constitutional sterilization by destruction of the pathologic germs and neutralization of the toxins.

Until methods are developed for a graded and certain general immunization we are forced to employ to the utmost extent the available methods for raising the patient's resistance. Two items stand in the foreground: restoration of proper elimination of waste products and neutralization of the toxins. Cathartics, flushings and diuretics will fall short of their purpose unless proper nutrition by the bloodstream is furnished to the eliminatory organs. Therefore the cardiovascular system calls for special attention. Preoperative preparation of the patient is just as important in electrosurgery as in any other form of surgical intervention. Specific resistance of the patient must be established. It is now generally accepted that practically all the defensive forces of the body reside in the reticulo-endothelial system. It was ascertained that the macrophages or histiocytes of this system are able to arrode and digest cancer cells, that they are the cells that imbibe, store and neutralize toxins, and that they are intimately connected with all phases of immunization. It was also ascertained that these cells are of a migratory tendency, that they may be attracted to any somatic area in which increased metabolism is excited and that their functional efficacy may be raised by the in-

* Read at the Eleventh Annual Session of the American Congress of Physical Therapy, New York, September 6, 1932.

hibition of foreign proteins and metallic compounds. It is claimed that the lack of therapeutic success is based on the fact that these defensive cells did not appear in sufficient numbers or that their funtcional capacity was not stimulated to the highest pitch, or that both these factors coincided.

The question necessarily arises what means are at our command for correcting such deficiencies. Electrocoagulation produces an abundant immigration of macrophages into the perithermic zone. But it is also of importance to maintain the influx of these cells from their points of original production. In order to accomplish this, systematic medical diathermy has to follow the coagulation, thus preserving an area of increased metabolism, at the same time enhancing lymphatic and hematic circulation.

Stimulation of the functional efficacy of the macrophages is attempted by the injection of proteins. At the present time autohemotherapy is our method of choice. For the combating of infections, however, the intradermal injection, as advocated by Dr. Corbus, seems to be more efficient than the usual intramuscular administration.

In order to excite an overproduction of macrophages we tried injections of a protein enzyme into liver and spleen. While we succeeded to a certain extent in this endeavor we are occupied now in testing other methods for obtaining better numeric results.

All these considerations may permit a plausible explanation for some clinical observations that at first glance appear to be somewhat paradoxic.

It seems that electrosurgery applied to cancers in organs that are surrounded by a bulky stroma provided with an abundant lymphatic and venous apparatus furnishes better results than if applied to organs where such a hinterland is lacking.

Electrocoagulation of cancers of the portio and cervix, of cancers of the rectum and of the base of the urinary bladder furnishes results very favorably comparing with the accomplishments of other methods while for instance cancers of the vertex of the bladder show very meager remote results.

While it has to be admitted that some of the views submitted are of a speculative character, one cannot help but feeling that electrosurgery is a stepping stone leading up to a biologic chemotherapy of cancer, to be developed by the intense collaboration of the surgeons, radiotherapeutists, pathologists and biologists.

May I be permitted to again express my conviction that the cancer question will not be solved in the operating room but in the laboratory.

DIATHERMY IN GYNECOLOGY

(FROM THE ELECTRICAL DEPARTMENT OF ST. BARTHOLOMEW'S HOSPITAL)

E. P. CUMBERBATCH, B.M. (Oxford), D.M.R.E. (Cambridge) M.R.C.P. (London)

Medical Officer in Charge of the Electrical Department of St. Bartholomew's Hospital

LONDON, ENGLAND

The writer deems it a privilege to contribute an article to this number of the ARCHIVES OF PHYSICAL THERAPY, X-RAY, RADIUM, issued in honor of one who may rightly be called the *Grand Mâitre* of high-frequency therapy, as an expression of admiration of the work of Professor d'Arsonval and in appreciation of the services which his researches on high frequency current have rendered to medicine.

The author and his co-workers are more specially associated with the use of diathermy in certain diseases of the pelvic organs in men and women. It might be of interest, perhaps, to give a brief preliminary account of the origin and development of this work, and the lines along which it has proceeded in the electrical department of St. Bartholomew's Hospital and afterwards in other hospitals. In 1913 a large number of cases of chronic arthritis were subjected to treatment by diathermy — the current being passed through the affected joints. The great majority of the patients were sufferers from rheumatoid arthritis and osteoarthritis. They derived little or no benefit from the treatment. Three patients who were suffering from gonococcal arthritis derived such great benefit from diathermy that it was decided to subject additional cases with this disease to the same treatment. The Great War, in 1914, delayed further investigation until 1919. It was then found that diathermy of joints was ineffective in some cases. The decision was reached to subject to diathermy the primary foci from which the infection was disseminated. It was realized that the parts which were secondarily infected could not be effectively treated unless infection of the cervix uteri or the prostate and seminal vesicles was eliminated. Many months were spent in devising methods for their diathermic treatment.

The greatest difficulty was experienced in the case of the insensitive cervix. The task was relatively easy in regard to the sensitive urethra. The aim was to heat the parts to the greatest possible degree without damaging them or causing pain. A tubular electrode was placed in the urethra and a belt electrode around the trunk to encircle the pelvis. The current was increased until the patient began to complain of pain in her urethra. It was then reduced until the pain just disappeared and heat alone was felt. To subject the cervix to diathermy a rod electrode was placed in the canal, the pelvic belt electrode remaining in position. The difficult task of ascertaining the current that would heat the insensitive part to the desired temperature was undertaken by the writer's colleague, Dr. C. A. Robinson. He calculated that if the diameter of the cervical electrode were the same as that of the urethral electrode, the current for the cervix should be one-half of the current required for the urethra, because the canal of the cervix is half the length of the urethra. The current would then attain the same density in the cervix as in the urethra, and the same temperature would be reached in both parts. This meant a preliminary treatment of the urethra and the measurement of the current that produced the maximum sensation of heat without pain. It was afterwards shown by means of thermometers that the cervix reached the same temperature as the urethra. It was found also that the temperature at which the sensation of pain began to be felt in the urethra, as indicated by a thermometer within the urethral electrode, was between 114° and 115° F. The subjection of the urethra to diathermy for the purpose of finding the strength of current that would heat the cervix to the same degree (and also for treating urethritis, if present) and the application of diathermy to the cervix immediately afterwards was called "the double treatment."

As soon as this method was adopted it was found that much better results were obtained in gonococcal arthritis and fibrositis. The next question considered was the influence of the diathermy *on the urethra and cervix them-*

selves — whether these parts were freed from gonococci. Clinical and bacteriological examinations were made and a "follow-up" was instituted. In the meantime the supply of cases of arthritis did not abate. In some there was a doubtful history of gonorrhea; in others no history and no evidence of it, hemolytic streptococci being found in the cervical secretion. All the cases were treated by applying diathermy to the cervix, the "double treatment" being employed. Its effect on the cervix and joints was recorded.

Next a trial was made of the effect of diathermy on gonococcal and non-gonococcal salpingitis. At first the treatment was administered *to the cervix* because that part was infected as well as the Fallopian tubes, and it was thought that the disinfection of the cervix would be followed by abolition of the infection in the tubes, just as cervical diathermy is followed by the disappearance of inflammation from the joints in cases of metastatic arthritis. It was soon found, however, that the heating of the cervix to 114° F. aggravated the salpingitis, causing an increase of pain and fever. It was then decided to try some method of applying diathermy which would heat the cervix less and the tubes more. A large vaginal electrode was devised. Its inner end made a metallic contact with the vault of the vagina and the vaginal aspect of the cervix. The same pelvic belt electrode was used as before. Currents of different strength were tried. It was found that the current which procured a temperature of about 108° F. in the region where the metal was in contact with the cervix gave the best results. Temperatures higher than 108° were not more effective. This was called the "single method." It was found that a current of 1.5 to 2.0 amperes, depending on the machine and the patient, was needed to attain 108° F. In the "double method" a current of 0.5, 0.6 or 0.7 ampere, according to the machine and patient, is used. But though it is only about one-third of that used in the "single method" it has a much higher density at the narrow intracervical electrode than when the broad metal electrode makes contact with the exterior of the cervix. Consequently the high temperature of 114° is in contact with the intracervical electrode, but little rise, if any, in the more distant tubes. On the other hand when the "single method" is employed there is a temperature of 108° on the vaginal aspect of the cervix, but as a much stronger current is used there must be a rise of temperature in the tubes.

While the influence of diathermy on salpingitis was under investigation, the importance of examining the cervix uteri in cases of arthritis was firmly established. In many cases there was no cervicitis and no clinical evidence of abnormality of the uterus or its adnexa. Many of the patients were at the climacteric. Others, who were older, dated the onset of their joint trouble to the time of change of life. In some the cessation of the menses was premature. The arthritis was of a different type than that found in cases of cervicitis. There was less pain; sometimes there was little or none. The knees and ankles were commonly affected. On the inner aspect of the knees was often found a thickening of the subcutaneous tissue. This was situated over the inner hamstring tendons. Ankylosis was never found. This type of arthritis is not caused by infection. It has been attributed to disturbances of the endocrine system associated with the climacteric. It has been named *menopausal* arthritis. Many believe that the thyroid gland is at fault. Cases of this kind were treated by pelvic diathermy, the "single method" being employed. The object at first was to ascertain whether diathermy had any influence on the menstrual function when the periods had stopped prematurely. It was found that menstruation returned, a few periods being noted by the patient. The record case was that of a woman who had ceased to menstruate at 38, and later developed arthritis. At the age of 48 she was sent to the writer's department. Pelvic diathermy was administered. Soon after a menstrual period occurred. There were other cases in which menstruation was restored after it had prematurely ceased for two or three years. These patients came to the hospital for relief from arthritis. Pelvic diathermy produced little alleviation in the cases in which the arthritis had lasted for a year or longer. But the effect was quite different in early cases, that is, before structural changes took place in the joints. The arthritis disappeared. During the two years that have elapsed since the commencement of the treatment of these early cases there has been no return.

The effect of pelvic diathermy on arthritis of the climacteric was the stimulus for further

study of this form of treatment in other troubles due to change of life. One of these is hyperpiesia. Pelvic diathermy, administered by the "single method" brought about a reduction of the blood pressure to normal. In one case an electrocardiogram was made before and after the course of treatment and a change was observed in the record. Dr. C. A. Robinson, who has made a special study of pelvic diathermy in relation to the climacteric, has concluded that the troubles that may occur at the time of the menopause, such as arthritis, hyperpiesia, etc., are due to disturbance of the endocrine function of the ovaries. There is no doubt that the ovarian endocrines influence certain systems of the body, such as the cardio-vascular, metabolic, articular, etc. This influence ceases at the time of the menopause. Why is it, then, that every woman does not suffer from arthritis, hyperpiesia, etc.? Because the internal secretions of the other endocrine glands compensate the deficient ovarian endocrines. But if the compensating action is too slow in its development, the ovarian endocrine function must be kept up longer. It is probable that diathermy exercises an effect of this kind. This, of course, is theory, but it serves to explain the fact that pelvic diathermy has a valuable therapeutic action in the changes by the climacteric.

When Dr. C. A. Robinson was palpating the inflamed cervix of a patient who had come for treatment of arthritis, the woman remarked that the pain in the lower part of her back was aggravated. This chance observation on the part of the patient led to a most important finding. Dr. Robinson discovered that many women who suffer from chronic low backache had infection of the cervix. Manual movement of this organ aggravated the pain. Consequently be sought for — and often found — cervicitis in women who had long been complaining of low backache. The usual type of patient was the mother of one or more children, who presented the toxic facies, complained of everlasting fatigue and depression, bruised easily, and who sometimes complained of pain in her joints as well as in her back. What had happened was undoubtedly as follows: Birth of a child, infection of the cervix, absorption of toxins, spread of inflammation along the lymphatics to the back, and, lastly, an arthritis of the infective (toxic) type.

It was found that the disinfection of the primary focus by diathermy caused the backache to disappear, the "muddy" complexion to clear up, the general health to become enhanced, and, lastly, the condition of the joints to improve. The final state of the joints depended on the extent to which permanent structural changes had taken place in them.

Cases of dysmenorrhea of the *spasmodic* type, which are notoriously difficult to relieve, were sent for a trial with diathermy. After the first course it seemed that the treatment was of some benefit. Continuation of the diathermy, however, was disappointing and the patients, without exception, relapsed in spite of perseverance with the treatment. The results were very different in cases of dysmenorrhea of the *congestive* type. Married women alone were treated. All the cases were apparently cured.

Accordingly the work done in the gynecological section of the Electrical Department of St. Bartholomew's Hospital during the past fourteen years may be summed up as: 1. The elaboration of methods of applying diathermy to the urethra, uterus and its adnexa. 2. The treatment of gonococcal infection of these parts and the metastatic complications. 3. The treatment of non-gonococcal cervicitis and its metastatic complications. 4. The treatment of salpingitis, dysmenorrhea and the difficulties that arise during the climacteric.

Comments and Conclusions

What has been called the "single method" of applying diathermy to the pelvic contents is practiced in one way or another by many workers. It is wrong to suppose that it will be effective in all cases of *cervicitis;* it will cure a few but not the majority. The "double method" was devised by Dr. C. A. Robinson. He has employed it for 12 years and it is the standard method at St. Bartholomew's Hospital, at the West Middlesex Hospital and at the London Light and Electrical Clinic. To use it successfully three requirements are absolutely essential. The operator must be familiar with diathermy. He must be experienced in intrapelvic manipulation. Lastly he must gain the patient's confidence and cooperation. If he fails to do so, she will complain of pain long before the urethral temperature reaches 114° F. and failure will result. The "double method" is always employed at the hospitals and clinic mentioned

for treatment of urethritis and cervicitis. The "single method" is used for the treatment of salpingitis (and oöphoritis), dysmenorrhea, and the troubles of the climacteric.

Conclusions as to Results. In the electrical departments of the hospitals and clinic abovenamed a cure is confidently expected and almost always obtained in gonococcal urethritis. Adverse comments have been made on these claims. The writer reads various journals on physical therapy. In one he noted the remark of a speaker who expressed his desire to go out of the room when the present writer stated that cure ought to be obtained in 100 per cent of female cases. On the occasion when the writer visited the United States (seven years ago) his experience had been derived from the most suitable type of case; that is to say, the patients came from a venereal department centre where a thorough trial of other methods had been made, but a cervicitis or urethritis persisted, and the secretion showed gonococci. There was no inflammation of the other pelvic contents and no metastasis. In 90 per cent of these a cure was brought about. If the patient is not a prostitute and there is no possibility of reinfection the writer still maintains that 100 per cent should be cured. Not long ago he attended a meeting of gynecologists and venereologists at which the treatment of cervicitis (including gonococcal) was discussed. One of the speakers showed pictures illustrating the horrible condition in which the patients were when they came for treatment. Vulvitis, vaginitis, warts and quantities of pus were present at the onset. Diathermy is not the proper treatment of eases in such a state, nor would the writer attempt it.

Non-gonococcal cervicitis responds equally well to diathermy and the cervix regains its normal condition. In gonococcal arthritis the application of diathermy to the cervix brings about relief of pain, reduction of swelling of the joints and increase of range of motion. Further benefit is obtained if the joints are subjected to diathermy, massage and movements. The final result depends on the extent to which permanent structural change has taken place in the joints. In non-gonococcal metastatic arthritis the same results are obtained as in gonococcal cases, but in a rather smaller proportion, viz., in 75 per cent of the patients.

In salpingitis (gonococcal and non-gonococcal) diathermy should not be administered if pus is present. If it is absent the treatment brings about the disappearance of all signs and symptoms.

In dysmenorrhea of the congestive type *in married women* diathermy has not failed in any of the cases. On the other hand it has done no permanent good in cases of the spasmodic type.

In regard to diathermotherapy in the troubles that arise at the climacteric, experience has been gained in the treatment of arthritis. As already stated, some cures appear to have been obtained in early cases. In cases of long duration, in which the patients no longer complain of flushing, irritability, etc., it is not worth while to apply diathermy to the pelvic contents (provided there is no cervicitis). Regarding the other troubles of the climacteric a sufficient number of cases has not yet been treated to justify a conclusion.

In this short *resumé* the author has written from his own experience and that of Dr. C. A. Robinson on a very large amount of work conducted in the hospitals and clinic named. The work is still going on, and will be demonstrated from every angle to any regular physician visiting our department.

D'ARSONVALIZATION IN HYPERPIESIS

F. HOWARD HUMPHRIS, M.D. (Brux.), F.R.C.P. (Edin.), M.R.C.S. (Eng.), D.M.R.E. (Camb.)

LONDON, ENGLAND

Over twenty-one years ago I published an article* entitled, "The Significance of Sphygmomanometric Readings." The most important item of that article pointed out the value of d'Arsonvalization in reducing pathological high arterial tension. My experience with the current of d'Arsonval was then of but barely ten years duration. Today, with over thirty years of its use, my appreciation is greater than it was then. Experience teaches — and thirty years' experience has taught me, that if d'Arsonval had conferred no other benefit upon suffering humanity than of giving us a means whereby hypertension can (when indicated) be safely and surely reduced, we owe him a debt of gratitude, and should accord him a niche high in the Temple of Fame. But as it is out of place in this article to refer to the many other activities of d'Arsonval, which have exalted him to a seat among the Immortals, we return to hyperpiesis.

The accurate recognition of this condition may be said to have begun in 1828, when Poiseulle introduced the U or V-shaped mercurial manometer. Since then progressive and painstaking physicians have gradually brought the subject to its present prominence.

It may be argued that high blood pressure is only a symptom, and not a disease *per se*, but it is a symptom of such importance that it urgently calls for relief.

"A man is as *old as his arteries*," and it is a high arterial tension which makes those arteries old. With d'Arsonvalization it is possible to keep in check the rising blood-pressure, prevent the ageing of the arteries, maintain those arteries youthful and elastic and so render our patient as *young as his arteries*.

Increased arterial tension is, in all probability, responsible for the degeneration of the muscular walls of the arteries. In fact, nothing else can be conceived — granted the pathologically increased tension on the persistently contracted arterioles—than that metabolism and nutrition of the muscle structure of the arteries should suffer. Muscle tissue in any part of the body degenerates under constant tension, a fact comparable to the loss of elasticity which rubber or any elastic material shows when subjected to constant weight, i. e., tension. Therefore, if we can treat this tension before it has had time to cause the degeneration, if we can so diminish the blood pressure and thus avoid the otherwise resultant loss of elasticity, surely we should do so.

In some cases, where the blood-pressure is giving rise to nervous troubles we can, I believe, by approximating the blood tension more nearly to normal, prevent those difficulties from ending in permanent disease, and from crossing that borderline between nervous disease and mental derangement, to which they are slowly but surely progressing. And in diseases, other than those of the nervous system, their course, favorable or unfavorable, may be influenced by the approximation to normal of a co-existing high blood pressure, always assuming — and this is a point that must ever be borne in mind — that the abnormal high tension be not compensatory. When there is a failing ventricular compensation no attempt should be made to lower the peripheral resistance, for that very resistance is an attempt on the part of Nature to compensate for the failure of another compensation; but these cases are in the minority. In the vast majority of cases the increased tension is due to the imperfect elastic recoil in the arterioles, (even with arterio-sclerosis), plus increased peripheral resistance, and it is in these cases that the current of d'Arsonval acts as a well-nigh specific — and a safe specific.

It may be interesting to note here that electrically there is a simple method of determining, whether or no, it would be wise to attempt to lower the pressure, that is to say, whether we have a simple imperfect elastic recoil, with increased peripheral resistance, or whether we have broken cardiac

* *The Clinical Journal*, (England), March, 1911.

compensation. If a patient connected with a Tesla coil, arranged in a manner similar to that of the autocondensation couch, show any lowering of pressure with a small current of 20-30 ma. we may conclude that the peripheral resistance is of vaso-motor origin and should be left alone. If on the other hand, no change in the sphygmomanometric reading is shown, then it may be taken that the case is a suitable one for d'Arsonvalization. Of course, it is superfluous to test every case in this manner; as a rule, it is easy to decide the class of case with which we have to deal.

Before going into the question of treatment I must reiterate my objection to the generally accepted statement, and one that is being taught to-day, that the rise of the maximum arterial tension with advancing age is normal. One authority * has laid down that for each two years of life, after the age of twenty, one millimetre should be the normal rise. I will admit that as a man gets older his tension usually rises, but I deny that this rise is normal or physiological. I maintain that this rise is a pathological condition, and that the pressure rises, not on account of his years, but on account of something wrong with his health. In my opinion, a man who has always lived a healthy, active, peaceful and temperate life, should have when he is sixty the same blood-pressure as when he was thirty.

The question of etiology, and how an increased arterial tension may be brought about by occupation, diet and other habits, disease and so forth is here out of place; but we will briefly discuss some of the signs and symptoms of this condition, and the way in which the d'Arsonval current meets these, i. e., the therapeutics of the current.

High blood pressure, especially in the presclerotic state, may exist without any symptoms, or with so vague and indefinite ones, as to be barely recognizable by the patient, and may, indeed, be only discovered by the sphygmomanometric reading.

There may be certain functional symptoms such as attacks of transient giddiness, headache, often intensified with the effort of mental concentration ("the sign of painful thought"), epistaxis, palpitation, slight edema of the ankles, dyspepsia, insomnia or drowsiness, with a disinclination to work, irritability of temper, a tendency to tire easily after bodily or mental exercise, anxiety or a sense of impending evil, impossible to define.

Thus it will be seen that a high blood pressure may evidence itself in a variety of ways, none of them pathognomonic; but they usually occur grouped together in such a way as to suggest an increase in the blood pressure. Once this condition is recognized, with d'Arsonvalization, properly administered, much more can be accomplished than with other physical or medicinal measures. Pathologically, there may exist a process of degeneration which we can check, and so prevent an arterio-sclerosis, and ward off such imminent consequences as apoplexy, renal complications and the many ills which follow in the train of an arterio-sclerotic condition. With the use of the d'Arsonval current, (except in very advanced cases), a patient can be kept for years in a condition of safety, and his expectation of life unaffected by the hyperpiesis — and with this he should be content.

The rationale of the current in lowering the blood pressure is at least two-fold. One, the general or constitutional effect, as affecting metabolism, and the other, local effect on the vasomotor system. The general effects of the current as influencing metabolism have been demonstrated both clinically and chemically. Shortly after commencing treatment there is a gain in physical and mental strength and a general improvement in the health of the patient, apparent not only to himself but to all around him. The symptoms, be they insomnia, headache, irritable temper, palpitation or anxious fears, disappear. Chemically there is an increase of solids in the urine, and a similar excretion has also been found on analysis of the perspiration.

The improvement in general metabolism is probably largely due to the effect of the current on the vasomotor system, whereby the arteries, becoming relaxed, permit of a better circulation of the blood; and if this one fact be granted, then the beneficial effects of the current are easily explained. A subsidiary cause may be at work, and that is the thermic effect of the current. This latter is quite apparent to the patient, and

* Faught: "Blood Pressure." Philadelphia, W. B. Saunders & Co.

it may be that this heat causes an increase of functional activity, by means of which, the elimination of toxic materials is augmented.

There are many instruments on the market which deliver the d'Arsonval current. It is essential, however, to choose one which is capable of giving a sufficiency of current, and by a sufficiency is meant 2500 ma. by the autocondensation method. I will briefly describe the arrangement which I have had in successful use over twenty years.

The current, 220 volts, is led from the direct main in the ordinary way, through a switchboard, to a 12-inch coil, the switchboard being provided with a voltmeter and ammeter, knife cut-out, and three resistances. Of the latter, one controls the speed of the interrupter, the other two regulate the strength of the current. From the coil, the current is led into a multiple spark-gap, choke coils being intercalated. From the spark gap it is led to two insulated condensers, having a capacity of 0.002 M.F.D.; thence it is led to an adjustable inductance resonator of copper wire, 4 B.W.G.; having 28 turns, from thence to one terminal a sheet of metal 18x68 inches, and to the other, ending in a metal handle, with a milliamperemeter in circuit. The spark gap is the one designed by Dr. De Kraft of New York City, and is of the simplest type. There are nine gaps each measuring 2 cm. The sparks are discharged unmuffled into the air, but owing to their shortness and the multiplicity of them they are virtually noiseless.

In 1912, I read a paper, in Berlin, describing this apparatus and the use of Dr. de Kraft's spark gap in conjunction with condensers, to enable a powerful d'Arsonval current to be obtained from the x-ray coil, and it is this apparatus which I have had in daily use until the present time. The patient rests on a cushion, which is placed on the sheet of metal. It is made of leather and filled with horse-hair, measuring 22 inches wide and 72 inches long and 3 inches in thickness. The patient holds the handle in his hands, and should feel nothing except a sense of warmth, chiefly in the wrists, as the current is slowly turned on and the meter registers 1,000 ma. or more. The current should flow for about ten minutes or until the patient becomes flushed or the skin moist. It should be repeated daily or two or three times a week, according to the nature of the case and the readiness with which it responds to treatment. The blood pressure should be about 10 per cent lower at the end of the treatment than at the beginning. It will gradually rise till the following day (but not always to its original height), when another treatment should be given. After a time it will be observed that the pressure no longer rises between treatments. This may be taken as the patient's normal pressure, and to keep it at this, and himself in a condition of safety, he should take treatment from time to time, as the varying conditions of his life and health may cause an increase in his pressure.

The importance of the d'Arsonval current, in its ability to lower a high blood pressure, can hardly be overestimated. If we can by it keep the arteries young, help to ward off mental disturbance in neurasthenics, diminish the chances of an unfavorable end of a case of nephritis, or forestall an attack of cerebral hemorrhage, then it is surely worthy of our earnest attention. These things — and more — are possible, by the lowering of arterial tension by the current of d'Arsonval.

ELECTROSURGICAL TONSILLECTOMY

Its Scientific Status in Laryngology

A. R. HOLLENDER, M.D., F.A.C.S.

CHICAGO

Differences of opinion have arisen about the value of electrosurgical tonsillectomy. A small number of laryngologists and a large number of general practitioners have employed this method in one form or another indiscriminately, and have become so enthusiastic as to assert that electrocoagulation of tonsils is an adequate substitute for surgical tonsillectomy. Such claims are not only unwarranted but bound to bring discredit upon an otherwise valuable addition to laryngology.

Electrosurgery cannot replace classic tonsillectomy, which will continue to be the method of choice in the overwhelming majority of cases. It is the author's conviction, based on experience and statistical studies, that there are less than five per cent of cases in which classic tonsillectomy is contradindicated. But even this represents a large clinical contingency, demanding another more suitable therapy.

Some favorable reports are on record on the respective merits of radium and roentgen irradiation for the treatment of inoperable tonsils. Schulte,[1] Schonfeld and Brumbach,[2] Knox[3] and others have expressed the belief that roentgen irradiation produces a good result without chronic injury of the mucosa or a disturbance in the functioning of the glands of the mouth and of the pharynx. Scal[4] treats inoperable tonsils with implantation of removable platinum radon seeds, and considers this procedure an adequate substitute for tonsillectomy where surgical intervention is contraindicated. According to this author, radium as compared with roentgen treatment, exerts its action only on the lymphoid tissues in the implanted area, without affecting the adjacent structures. The roentgen rays affect all the tissues and produce annoying after-effects. Electrocoagulation, too, is deprecated by Scal, because of the possibility of damaging adjacent structures even by skillful operators.

These and other reports in the literature show that the efficacy of radium and roentgen irradiation of tonsils is a controversial topic. While this holds good also for electrosurgery it must not be forgotten that there are hazards in all of these methods as well as in classic surgery.

Electrocoagulation, more than radium or roentgen irradiation, has appealed to the clinician, because it renders possible the ultimate complete extirpation of tonsils. Radium and roentgen irradiation have fallen short so far, which accounts for their not having been more widely adopted. While their use is occasionally indicated, the present trend points to electrosurgery as the most reliable substitute for classic tonsillectomy. Good therapeutic results may be anticipated in properly selected cases, provided the operators possess the requisite technical skill and judgment.

A number of articles on electrocoagulation of tonsils have been published during the past few years, but none has presented all the essential facts on this important subject. This paper, therefore, will treat the various aspects of electrosurgical tonsillectomy, with a view of establishing its rationale in laryngologic therapy.

Definition of Electrosurgery

So many practice electrosurgery without possessing even a fundamental knowledge of the current employed, that a brief definition of this method is timely. Kelly and Ward[5] define electrosurgery as the employment of an alternating electric current of 1,000,000 to 2,000,000 oscillations per second for the destruction or excision of diseased tissues. *Electrocoagulation* is accomplished by the use of two terminal electrodes, the active or operating electrode being the smaller and the indifferent or dispersive, the larger of the two. The dispersive electrode is usually placed on a remote part of the body. Coagulation of tissue of a depth of penetration varying according to the technic, takes place at the site of the operating (active) electrode. Two active electrodes of equal size, such as heavy needles insulated to half or three-quarters their length, can be utilized for electrocoagulation of small blocks of tissue, coagulation taking place in

the tissue between the electrodes and immediately around them. Active electrodes of the single type may be of any shape and vary from needles or balls to curets or wire loops.

Electrodesiccation is effected by means of a uniterminal high frequency current of higher voltage. The source is the Oudin or Tesla terminal of a high freuency apparatus. The tissue reacts by dehydration, its destruction being more superficial than that by electrocoagulation. The result is obtained by minimum heat and maximum voltage. Electrodesiccation should not be confounded with electrocoagulation or with *fulguration*. The latter produces rapid superficial carbonization of tissue without deep penetration of the current. As this method is quite painful, it is not frequently employed. Its selective application is limited to accessible small lesions. Occasionally it serves also to check surface oozing.

A lamentable misunderstanding to the effect that electrosurgery has the action of a cautery still exists, but the difference between them is fully appreciated by those who have investigated the subject. Here it suffices to point out that charring or burning of the cautery does not take place in electrosurgery, and this factor greatly increases the efficacy of electrosurgical methods as compared with cauterization of neoplastic diseases, a principle applying equally in surgery of benign tissue. As Kelly and Ward[5] state: "The cardinal virtues of electrosurgery lie in its effective destruction *in loco* of tissues that it is desirable to eliminate. . . . There is no handling of tissues because of the knife and fork type of operation, which is unequaled in cleanliness by the immediate complete sterilization of both bacterial and malignant infection."

Indications for Electrocoagulation of Tonsils

All sorts of indications have been advanced for this newer method of tonsil removal. For those who indiscriminately prefer electrocoagulation to surgery as a routine, rationalization of indications holds no interest. For those, however, who desire to limit the procedure to that small group of patients with definite contradindications to surgery, this phase of the subject is of scientific and practical value. Fowler[6] classifies the contraindications to surgical tonsillectomy under five distinct headings: 1. Acute infection, 2. Age, 3. High blood pressure and arteriosclerosis, 4. Bleeders, 5. Pregnancy. In the light of our present knowledge this classification is incomplete.

When removal of the tonsils is necessary in a patient over sixty, the choice of the method depends largely on his general condition. If there is doubt about the safety of surgery, electrocoagulation presents a satisfactory means of extirpation. This is true also in patients with marked hypertension and arteriosclerosis.

A decided indication for electrocoagulation of the tonsils is hemophilia. Delayed clotting time of the blood calls for electrocoagulation, because it is nearly always a bloodless procedure.

While tonsillectomy has been performed successfully in a large percentage of cardiac patients, the electrosurgical method is preferable because shock is avoided. The author[7] has carried out electrocoagulation in more than forty patients with all sorts of cardiac lesions. Likewise the removal of the tonsils in the tuberculous[8] has been accomplished with good results by so-called fractional electrosurgery without unfavorably influencing the pulmonary process.

One of the difficult problems with which the laryngologist has been confronted is recurrence of lymphoid tissue after classic tonsillectomy. Stubs, tags, and lymphoid remnants in tonsillectomized patients harbor infection,[9] and therefore require complete destruction or removal. Shall we employ surgical excision with its uncertain end results, or shall we resort to electrosurgical extirpation by the fractional method?[10] All who are familiar with both methods prefer the latter in spite of the fact that it is time-consuming. The patient is placed at no disadvantage or inconvenience and readily submits to the treatment. If electrosurgery in laryngology served no other purpose than the destruction of tonsillar remnants, it would still be a valuable contribution to this specialty.

Fungus infection of the tonsils which has resisted the usual text-book treatment has responded favorably to electrocoagulation.[11] Hypertrophy of the lingual tonsil and lymphoid tissue of the posterior wall and lateral folds of the pharynx have been reduced by a special method of electrocoagulation puncture.[12]

Neoplasms of the tonsil, particularly the malignant types localized in character, are more rationally managed by electrosurgical procedure. Dan Mackenzie[13] has given three

reasons for its preference in operating on pharyngeal cancer:

1. It prevents the operator from squeezing live cancer cells into the lymphatic vessels draining the affected area.

2. It prevents the sowing of the operation field with living cancer cells.

3. It destroys the bacteria of sepsis in the tissues adjoining the field of operation.

Virtually all writers on electrosurgical tonsillectomy have included in the indications for this procedure "the patient's arbitrary refusal of surgery."[14] This is not a scientific indication,[15] but it suggests the question: "Does the patient's preference for a special method justify its use by the surgeon?" The surgeon should always be the judge to decide on the procedure best suited for an individual patient.

Failure of Electrosurgical Tonsillectomy

The fact that a number of general practitioners and not a few specialists have experienced failures with electrocoagulation of tonsils, has prompted investigation of the probable causes.. In the opinion of the author, these are:

1. *Poor Illumination* — Obviously any attempt to operate in a pharynx without good illumination indicates a lack of regard for fundamentals. This is more important than is generally appreciated. The specialist trains himself in this preliminary essential while the general practitioner often disregards the value of it. Poor illumination is frequently the cause of unsatisfactory results with electrocoagulation.

2. *Injury to Normal Tissues* — Incorrect set-up of the high frequency machine and lack of control of the active electrode are occasionally responsible for failure. A foot-switch is an indispensable part of the equipment. The insertion into the pharynx of the active electrode with the current on and the sparks flying in every direction has been the cause of considerable tissue injury which can be avoided with correct technic.

3. *Inadequacy of Anesthesia* — Topical anesthesia, which is the only desirable anesthesia for electrocoagulation of tonsils, is seldom completely adequate for this method. There is always some discomfort, a fact which some operators fail to appreciate in their haste to complete the treatment.

4. *Lack of Patient's Co-operation* — At the first treatment the patient may show considerable apprehensiveness when the operator has failed to explain what the method entails. The probability of some discomfort should be clearly stated. The apparatus should be turned on to demonstrate the spark-gap noise and the absence of electrical shock. The patient should also be told that there is a varying amount of after-discomfort.

5. *Lack of Operator's Training and Experience* — "The operator should have a thorough knowledge of the structure of the throat, of pathologic changes incident to removal of the tonsils, and of the possible complications associated with the electrosurgical method."[16]

Technic of Electrosurgical Tonsillectomy

Like many therapeutic procedures, electrosurgical tonsillectomy lacks a standardized technic. This is due to the fact that the method is far from perfected and that many an operator has attempted to improve old or devise new electrodes and apparatus. Some have also shown a preference for different currents. Clark[17] still maintains that electrodesiccation is the most desirable means of tonsillar extirpation, while many workers, who have but recently become adherents of electrosurgery, claim better results with electrocoagulation.

The single and double needle[18] active electrodes call for different technics. The several types of indifferent or dispersive electrodes varying from block tin squares, metal tongue depressors[19] and metal cylinders to different shaped pillar retractors[20] have aided in confusing the novice. There is no necessity to modify a simple technic, if it is adequate. The single needle electrode and the block tin dispersive electrode have best served the purpose and require no modification for the average case.[21]

Some accessories are required, but these need not be of special design or make. Wooden tongue depressors and ordinary surgical pillar retractors are easier to work with than some of the specially devised instruments. So far as the high frequency apparatus itself is concerned, it should be of good construction and of sufficient capacity to give a good, smooth current of an intensity needed for tissue coagulation.

The plan of combining desiccation with coagulation or coagulation with fulguration[22] is neither necessary nor conducive to good end results. The electrocoagulating current pro-

duces every desired effect. Furthermore, the use of a single current facilitates the simplest form of procedure.

Disadvantages of Electrosurgical Tonsillectomy

In a presentation of all facts it is proper to point out the disadvantages of electrosurgical tonsillectomy. They are:

1. *Fractional Treatments* — Complete extirpation of the tonsils requires ten to twelve treatments. While it is possible to complete the work in a lesser number, the purpose of the method is defeated thereby. The one-stage operation, which is theoretically good, has been attended with so many drawbacks that it is no longer advocated by ethical practitioners. The removal of tonsils in one sitting by electrocoagulation promises no advantages over surgical removal. While fractional treatments necessitate repeated processes of destruction until a clean fossa is obtained, this plan avoids the severe local reaction of the one-stage operation. The fractional method, therefore, has only the disadvantages of repeated treatments.

2. *Preparation of Patient* — For the average patient very little preparation is necessary for a single treatment. However, for individuals who do not easily tolerate manipulation in the pharynx, the preparation for each treatment consumes as much time as that required for surgical removal.

3. *Lack of Uniformity of Technic* — Several aspects of this subject have already been discussed. The confusion incident to the many advocated procedures has made many practitioners reluctant to avail themselves of this newer means of tonsil removal, even though they appreciate that it merits a place in laryngology.

4. *Secondary Bleeding* — Secondary bleeding is only occasionally encountered by even experienced workers, but its possibility should be borne in mind. Premature separation of the coagulum may result from one of several causes, and gives rise to secondary bleeding.

5. *Adult Procedure* — Electrosurgical tonsillectomy is suitable only for adults of an age who would ordinarily consent to local surgical operations.

Advantages of the Fractional Electrocoagulation Method

There are certain advantages of the multistage plan of gradual extirpation of the tonsils. These advantages have no special significance in routine work but play an important role in the relatively few patients not regarded as belonging to the class of safe surgical risks.

The advantages may be listed as follows:

1. *Absence of Shock* — This is always of moment, but especially so when the patient has a cardiac disturbance, pulmonary tuberculosis, or other serious organic disease.

2. *Absence of Hemorrhage* — Primary bleeding is rare. If it occurs it is due to faulty technic. Secondary hemorrhage may occur but it is uncommon. The fact that bleeding is nearly always absent makes the method desirable for hemophiliacs and for patients with delayed blood clotting time.

3. *Sterilization of Infective Focus* — Prompt sterilization of the tonsil follows one or two treatments. It was observed that when the tonsil was the infecting focus in a generalized arthritis, the symptoms were relieved long before all the tonsillar tissue was extirpated.

4. *No Interference with Regular Nutrition* — The discomfort of an electrocoagulation treatment is slight and does not interfere with swallowing or the intake of food. This is of special advantage in the presence of certain systemic diseases during which the loss of a single meal may weaken the patient.

5. *No Systemic Upset* — Except in very nervous persons, systemic upset following an electrocoagulation treatment is rare even in the presence of active pulmonary tuberculosis.

6. *Economic Aspect* — It is obvious from what has been stated above that fractional electrocoagulation of tonsils does not interfere with the patients in the performance of their regular duties.

7. *Hospitalization Avoided* — The treatments being an office procedure, hospitalization is avoided.

8. *Control of Procedure* — The procedure can be accurately controlled and produces a minimum amount of scar tissue, a clean, smooth fossa and a pharynx in which the normal structures are uninjured.

Comparison of End Results of Surgical Enucleation and Electrosurgical Extirpation of Tonsils

The general opinion that the end results of surgical tonsillectomy depend more upon the ability of the surgeon than on the merit of technic is partly responsible for the increas-

ing number of new methods which have been advanced. The objective should be complete removal of tonsillar tissue, irrespective whether surgery or other means are employed. If all the tissue is not removed, the resulting condition is likely to produce more severe symptoms than existed before operation. This has been established by numerous investigations.

According to Fowler,[6] "recurrence of lymphoid tissue in or about the tonsillar bed is reported wherever follow-up work is accurately done. In a series of such examinations in one of the large New York hospitals, several years ago, the whole fossa was clear and the pillars intact in 60 per cent of the cases. Of the other 40 per cent the majority had marked pieces at the base."

Another comment based on the work of Rhoads and Dick,[9] who found tonsillar stumps in the throats of 73 per cent of persons who had undergone tonsillectomy, is that made by Painter.[23] "In my work at the Research Diagnostic Clinic, I often feel greatly chagrined to have the patient state emphatically that his tonsils are out because they were removed by a specialist, only to find a miserable looking throat, with badly infected stubs and a considerable scarring. These patients come from a wide area; the condition exists all over the country. We have the privilege to demand tonsil work only as we merit it, by at least reversing our figures of 73 per cent postoperative results instead of the 27 per cent or less as it stands today."

These statements and many similar ones from authentic sources indicate that surgical tonsillectomy has not been a panacea for perfect end results and that the tonsil problem merits further research. It is quite possible that electrosurgery may bridge the gap, and even though it falls short in many ways of replacing surgery as a routine procedure, it may prove eventually to be a valuable adjuvant.

Electrosurgery is in a stage of development. For tonsillectomy it has not yet passed beyond experiment. As is the case with surgery, electrocoagulation is far from being a panacea, and its end results depend largely on the ability of the operator.

The electrocoagulating current is capable of destroying every remnant of tissue in the tonsillar fossa. Inasmuch as this can be accomplished by perseverance, the only criterion of perfection is the ability to determine when complete extirpation has been effected.

Conclusions

1. Electrosurgical tonsillectomy is offered as a substitute for surgical tonsillectomy for less than five per cent of all patients requiring removal of their tonsils.

2. For this small group the method possesses certain advantages, and is decidedly less hazardous than surgery.

3. The method has definite disadvantages and limitations, and should not be heralded as a solution of the tonsil problem.

4. The main purpose of this contribution is to present all the facts without bias, in order to establish the rightful place of the fractional electrocoagulation method of removing tonsils in the practice of laryngology.

The above contribution is dedicated to Professor Arsène d'Arsonval of the Institute de France, as a tribute to his genius which made possible the use of high frequency surgery and diathermy in rhino-oto-laryngology.

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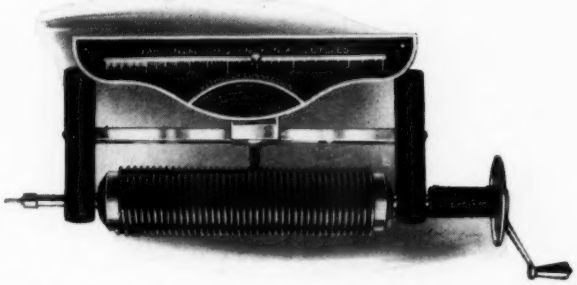

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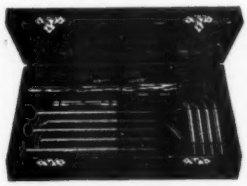

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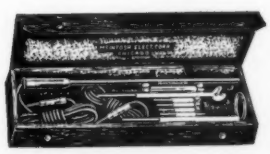

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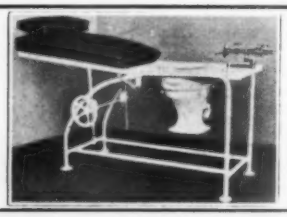

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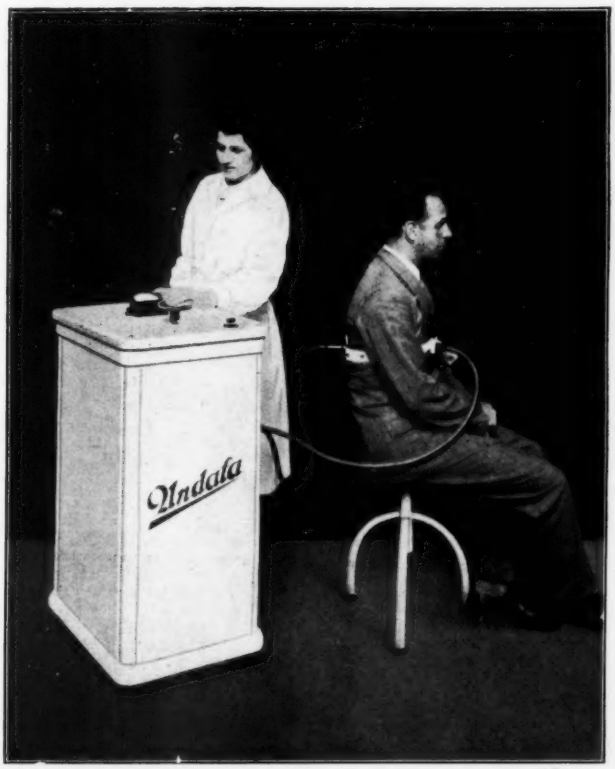

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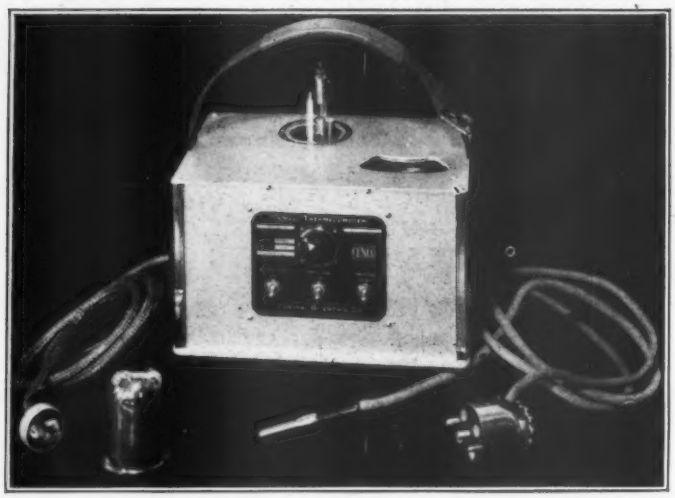

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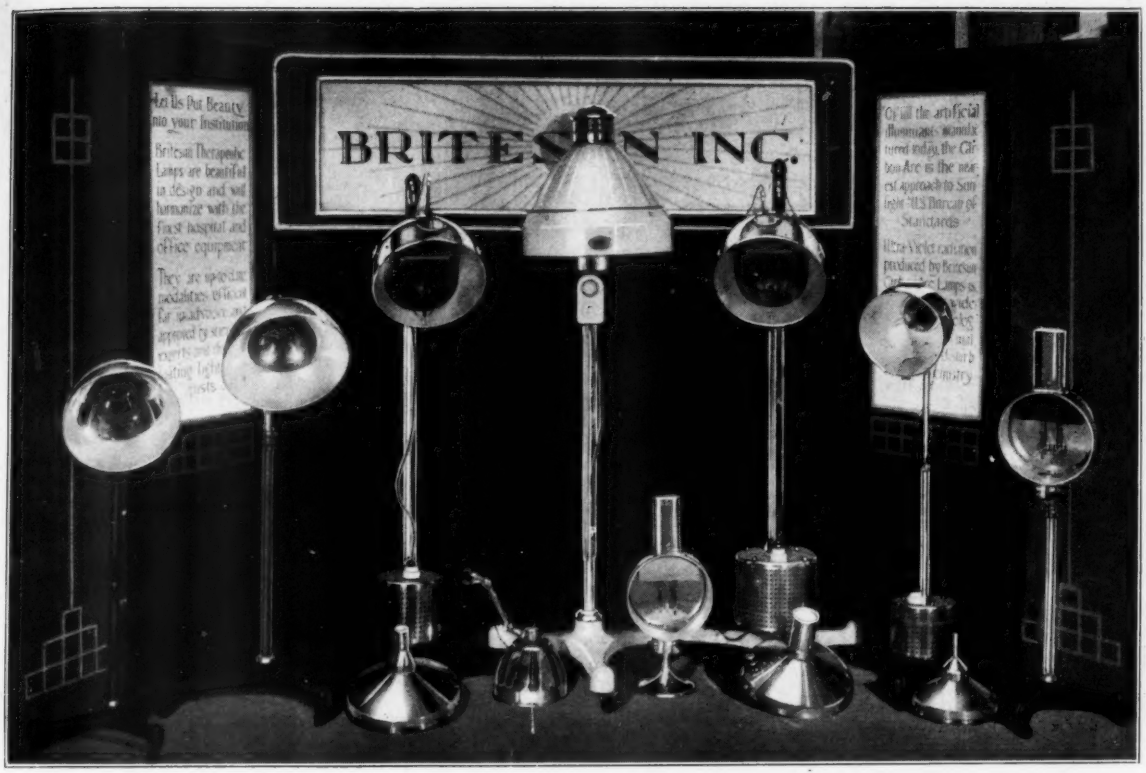

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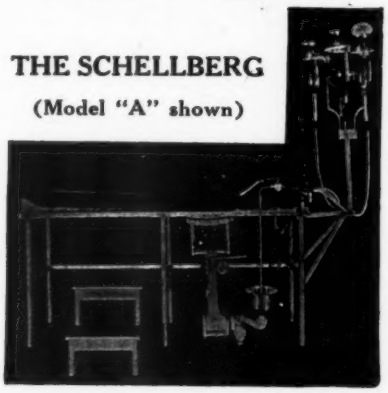

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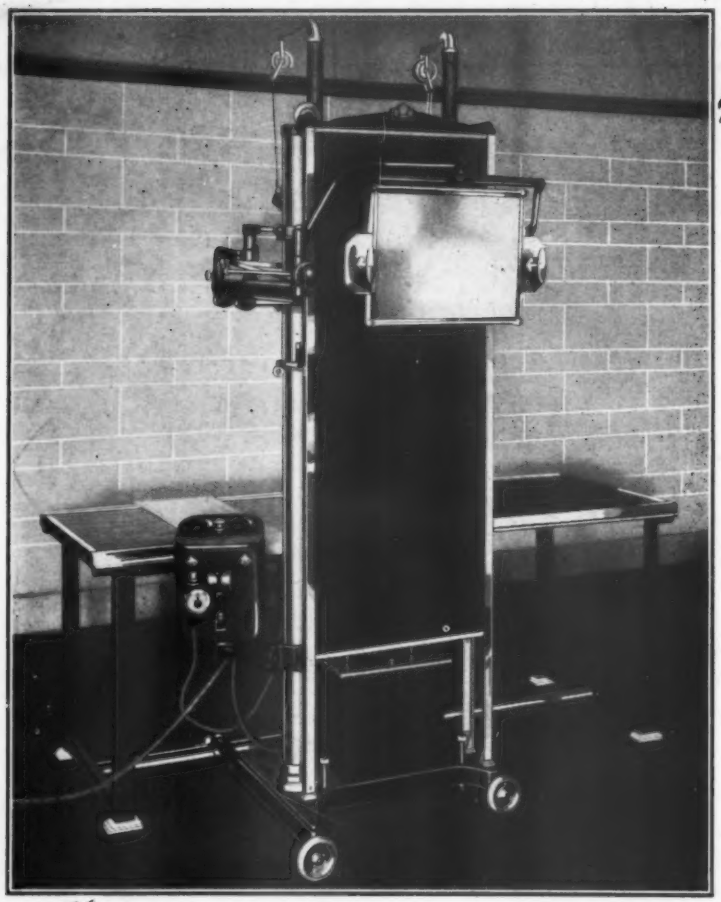

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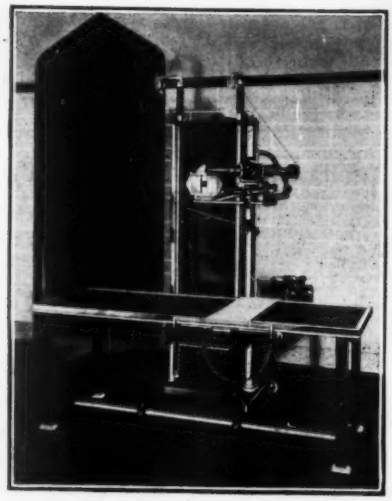

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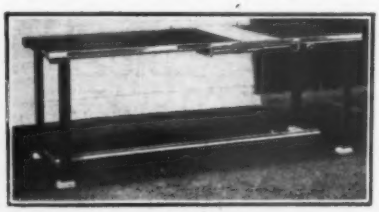

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